NATURAL THEOLOGY:

OR THE

EVIDENCES OF THE EXISTENCE AND ATTRIBUTES OF THE DEITY.

HENRY LORD BROUGHAM, F.R.S.

AND

SIR CHARLES BELL, K.G.H., F.R.S.

III.

NATURAL THEOLOGY:

OR THE

EVIDENCES OF THE EXISTENCE AND ATTRIBUTES OF THE DEITY

VOL. I.

LORD BROUGHAM'S INTRODUCTORY DISCOURSE; AND ARCHDEACON PALEY'S NATURAL THEOLOGY.

VOL. II.

ARCHDEACON PALEY'S NATURAL THEOLOGY; SIR CHARLES BELL'S ILLUSTRATIONS; AND LORD BROUGHAM'S DISSERTATION ON THE ORIGIN OF EVIL, &c.

VOL. III. (*Supplementary Volume.*)

LORD BROUGHAM'S DIALOGUES ON INSTINCT AND DISSERTATIONS ON FOSSIL OSTEOLOGY; AND SIR CHARLES BELL'S TREATISE ON ANIMAL MECHANICS.

III.

NATURAL THEOLOGY

OR THE EVIDENCES OF THE

EXISTENCE AND ATTRIBUTES OF THE DEITY:

CONTAINING

Dialogues on Instinct,

AND ANALYTICAL VIEW OF

THE RESEARCHES ON FOSSIL OSTEOLOGY.

BY

HENRY LORD BROUGHAM, F.R.S.

AND MEMBER OF THE NATIONAL INSTITUTE OF FRANCE;

AND

Animal Mechanics,

OR PROOFS OF DESIGN IN THE ANIMAL FRAME.

BY

SIR CHARLES BELL, K.G.H., F.R.S.

PROFESSOR OF SURGERY IN THE UNIVERSITY OF EDINBURGH.

LONDON AND GLASGOW:

RICHARD GRIFFIN AND COMPANY,

Publishers to the University of Glasgow.

1855.

London: Printed by W. Clowes and Sons, Stamford-street

DIALOGUES ON INSTINCT.

BY

HENRY LORD BROUGHAM, F.R.S.

CONTENTS.

FIRST BOOK, OR DIALOGUE.—(FACTS.)

SECOND BOOK, OR DIALOGUE.—(THEORY.)

THIRD BOOK, OR DIALOGUE.

ANIMAL INTELLIGENCE.—(FACTS.)

FOURTH BOOK, OR DIALOGUE.

ANIMAL INTELLIGENCE.—(THEORY.)

NOTE TO THE DIALOGUES.

NOTE ON THE GLOW-WORM.

ANALYTICAL VIEW OF CUVIER'S RESEARCHES ON FOSSIL OSTEOLOGY, AND APPLICATION TO NATURAL THEOLOGY.

Labours of Cuvier's Successors.

Notes on the Fossil Osteology.

General Note Respecting Evidences of Design.

Place—BROUGHAM, IN WESTMORELAND.

Time—SEPTEMBER, 1837.

Persons—*A.* LORD SPENCER (ALTHORP).

B. LORD BROUGHAM.

OF INSTINCT.

BOOK, OR DIALOGUE I.

INSTINCT—Introduction; (Facts).

When the General Election of 1837 was near its close, and every day brought the accounts of those mighty boasts of our expected successes under the new reign, so idly made, being overthrown by the activity and resources of our adversaries and the listlessness of the people on our behalf, Lord A. came to me on his way to the North, where he was minded to diversify with field-sports his habitual life of farming. Those pursuits had never interfered with the duty he owed his country as long as he deemed that the sacrifice of all his domestic comforts could prove serviceable to his public principles; nor had they ever at any time prevented him from cultivating a sound philosophy, in the study of which much of his leisure is always consumed. When I passed a few days with him at Wiseton, the summer before, we had discussed together some of the more interesting topics which form the subject of these speculations, connected with Natural Theology, though of a substantive interest independent of the relation in which they

stand to that sublime inquiry; and, while I remained at Harrington, we had corresponded constantly on the subject of Instinct, one of the most curious in its minute details and of the most interesting in its bearings upon the philosophy of mind, independent of its immediate connexion with theological speculations, but, it must at the same time be admitted, one of the most difficult, and upon which the labours of philosophers have cast a very imperfect light. It was natural then that we should renew these discussions when we afterwards met in Westmoreland. The weather being fine, we ranged somewhat among the lake scenery, and by the rivers and through the woods which variegate our northern country. There was not much to tempt us in the aspect of public affairs, which, if not gloomy for the country at large, was yet not very flattering for the liberal party, among whom the single object seemed now to be the retention of office, and who might say with the Roman patriot in the decline of liberty,—"Nostris enim vitiis, non casû aliquo, rempublicam verbo retinemus, reapse vero jampridem amisimus."* Nor, indeed, on these matters was there a perfect agreement between us two; for while we augured as little favourably the one as the other of our prospects, we ascribed to different causes the condition of affairs which gave rise to these forebodings: he, tracing it to the great natural weight and influence of the Tories throughout the country, both in church and state; I, relying more on the energies of an improved and active people, provided the government

* "By our own misconduct, not by any calamity, though we may still have the name of a free government, we yet have lost the reality."—Cic. Frag. de Rep. lib. v.

had acted so as to merit their support, but lamenting that no pains had been taken by them to show any superiority of popular principles, or make the country feel itself better off under their rule than they would have been under the adverse faction, while I perceived sufficiently plain indications that the accession of the Court favour in this new reign would have the effect of lessening rather than promoting any popular tendencies which might still exist. Altogether, therefore, the state of the commonwealth was a subject less suited to engage our conversation; and we naturally dwelt little upon passing and unpleasing topics, as unsatisfactory, transitory, and fleeting—"ista quæ nec percunctari nec audire sine molestiâ possumus."* But upon those matters of permanent interest and universal importance, and which the follies or faults of men could not despoil of their dignity or deprive of their relish, we loved to expatiate; and coming to the island in the neighbouring river, found a convenient seat where the discussion might be carried on under the cool shade which the wood afforded against an autumnal sun: "Here," said I, "we may resume our Wiseton conversation."—"Ventum in insulam est. Hâc vero nihil est amœnius; utenim hoc quasi rostro finditur Fibrenus, et divisus equaliter in duas partes latera hæc alluit, rapideque dilapsus cito in unum confluit, et tantum complectitur quod satis sit modicæ palæstræ loci; quo effecto tanquam id habuerit operis ac muneris ut hanc nobis efficeret sedem ad disputandum, statim præcipitat in Lirem."†—"Here," said I, "we may

* "Things which we can neither inquire about nor hear without vexation."—Cic. Acad. Quæst. lib. ii.

† "We came to the island. But than this spot nothing

resume our Wiseton conversation;" "si videtur considamus hic in umbrâ, atque ad eam partem sermonis ex quâ egressi sumus revertamur."*

A. Have you reconsidered my opinion, or rather the inclination of opinion, which I had last year, that it will be advisable, if not necessary, to begin with defining Instinct, in order that we may the more clearly understand what we are discussing?

B. I have indeed; and I remain of my own, as often happens through obstinacy and unwillingness to give up a preconceived notion; but here it is, I believe, from much reflection upon the subject, that I still regard the definition as rather the end of our inquiry than its commencement. Indeed, this may generally be observed of metaphysical, or rather psychological inquiries: they are not like those of the mathematician, who must begin by defining; but that is because his definition is, in fact, a statement of part of the hypothesis in each proposition. Thus, whoever enunciates any proposition respecting a property of the circle predicates that property of a figure whose radii are all equal; and it is as if he began by saying, "Let there be a curve line, such that all the straight lines drawn from its points to another point within

can be more agreeable; for here the Fibrenus is split as by the prow of a vessel, and being divided into two equal branches, washes the sides; then, after rapidly separating, it quickly unites in one stream, embracing space enough of ground for a moderate-sized place of exercise: after which, as if it only had the work and office of providing us with a seat for our discussion, it straightway falls into the Liris."—Cic. de Leg. lib. ii.

* "If you please we may here sit down under this shade, and revert to that part of our conversation from which we had departed."—Cic. de Leg. lib. ii.

it are equal, then I say that the rectangles are equal, which, &c." The general definition only saves the trouble of repeating this assumption, as part of the hypothesis in each proposition. But the nature of instinct, or of any other thing of which we discourse in psychology, is not the hypothesis we start from; it is the goal or conclusion we are seeking to arrive at. Indeed, so it is in physical science also; we do not begin, but end, by defining the qualities of bodies, or their action on one another.

A. I grant this. But if there be more things than one which men call by the same name, for example, of Instinct, must we not begin by ascertaining what we mean by the word, in order to avoid confusion? And this seems to bring on the necessity at least of some definition.

B. I agree that there must in this case be a definition; but it is only a definition of terms, and does not imply our stating the nature of the thing defined: it only implies that we must understand what the thing is to which the given word applies, and, if two things go under the same name, that we should be agreed in the outset which of the two things we mean when we use the word; perhaps, that we invest some second name, or give some qualifying addition to the given one, to express one of the two things, and keep the different meanings distinct.

A. The best way will be that we should come to particulars—give an example or two: perhaps it may suffice to mention the different kinds of Instinct, if, which I take for granted you do not doubt, there be more things than one going under that name.

B. Certainly; and there can here be no difficulty at all in our way; and, to show you how little alarmed I am at defining, when it is clear that I am only called upon to define a word, and thereby make a distinct reference to a thing known or unknown in its own nature—not to pretend giving an account of that nature—I will at once begin by both inventing names and defining their meaning. There are some Instincts which may be called *physical*, and others *mental*, in the animal system; by physical I mean those actions or motions or states of body which are involuntary; as the action of the heart, and the peristaltic motion of the bowels, over which, generally speaking, we have no direct control by the operation of the will—for I put out of view such rare instances, almost monstrous, as Darwin has recorded of a person who could suspend the pulsations of his heart at pleasure, and another, still more rare, of one who could, at will, move his bowels by accelerating the peristaltic action.* Even if all men could acquire such control over those motions, they would still be involuntary; because they could still be carried on wholly without our will interfering, and without our minds necessarily having any knowledge whatever of them. So the secretions are all performed involuntarily, and may go on wholly without our knowledge; we can affect them as we can the involuntary motions of the heart and fluids, indirectly, because the passions and feelings of the mind have always an effect upon them; but still they exist and proceed, the parts perform their functions, and those functions serve the ends of their appointment, wholly independent

* Zoonomia.

of our will, or of any effort whatever on our part. We can affect them also immediately through the influence of physical agents, voluntarily applied as stimulants or sedatives, or the operation of voluntary motion, as well as mediately by the power which the mind derives from its union with the body; but they can go on of themselves, and, in all cases of healthy condition, go on better without any the least interruption on our part than with it.

A. This is certain: my only doubt is whether these can be justly or correctly termed instinctive operations at all. When I speak of Instinct, I mean something very different; namely, those voluntary movements, or that voluntary action of the mental faculties which is contradistinguished from reason. However, there is no harm, but much convenience, in beginning by defining and classifying, so as to leave on one side the physical and involuntary instincts—those things which may properly enough be called incidents of animal life, because there seems great difficulty in drawing a line between such motions and actions and those which subsist in vegetables.

B. There does certainly appear to be this difficulty. I hardly see how any line can be drawn between the motions of the lowest species of animal, the mollusca for instance, and those found in plants. There is in both organized form, a system of vessels, growth by extension not by apposition, a circulation of fluids and secretion of solids from those fluids, or of one fluid from another. There is also production of seed, and from the seed continuation of the species. But it is not only convenient that we should define in order to leave on one side what we are not to discuss, that it may not confound our

inquiry; the definition and classification may also carry us on, some little way, in our argument with respect to the other class of Instincts, Instinct properly so called, the Mental Instincts; at least, it seems to furnish us at the very outset with an analogy.

A. I have a dread, at least a suspicion, of all analogies, and never more than when on the slippery heights of an obscure subject; when we are as it were *inter apices* of a metaphysical argument, and feeling, perhaps groping, our way in the dark or among the clouds. I then regard analogy as a dangerous light, a treacherous *ignis fatuus*.

B. It is even so, if we follow it beyond where we can see quite clear and find a firm footing. But all light is good, and the best way is not to despair, still less put out any glimmering we have, but rather to increase it by adding others, or make it available by using apt instruments. However, we are getting too metaphorical: only it is my comfort that you began, and that I am led astray by one who (as you said in your inimitable letter to your Lancashire antagonist) is not one of "the eloquent people." But to return from where your poetical imagery led us—analogy may sometimes illustrate, and it may often lead to useful and strict inquiry, by suggesting matters for comparison and investigation.

A. Then what comparison do you make between the two kinds of Instinct? or rather, as the question is of analogy, how do you state a relation of the mental Instinct, which we shall call Instinct simply if you please, similar to or identical with some relation of physical Instinct?

B. As thus—the physical Instincts are indepen-

dent of will, or mind altogether, though they never are found except where animal life and consequently mind exists; but yet mind may influence them. Just so the mental Instincts are independent of reason altogether, though they are found in union with it and reason may influence them. It is a question if they are ever found without reason; for that depends on our solution of the *vexata quæstio*, "Whether the lower animals have reason at all or no?" Therefore, I will not say that here the analogy is complete, and will not affirm that, as physical Instinct is never found without animal life, so mental Instinct is never found without reason; but we may safely say that in this other respect the analogy is perfect, namely, that where mental Instinct is found with reason it can act without reason, though reason may also interfere with it; and in this respect, at least, reason seems to bear the same relation to mental Instinct which animal life bears to physical Instinct. We may go further, and add, that as in plants, where the motions are without animal life, those motions are more perfect and more undisturbed, so if there be any animal wholly without reason, the operations of mental Instinct are the more regular and perfect; and, in any animal whatever, they are so in proportion as reason is dormant or inactive.

A. It may be as you say; but this will not carry us, as you seem to be aware, far on our road. However, it is well enough to remark it; for we thus gain perhaps a clearer and more steady view of the relation between Reason and Instinct, always supposing that there is any warrant for treating the two as different: because you are aware that some have considered them as identical: I mean

not merely by denying that there is any specific difference, any difference in kind, between our faculties and those of brutes—though this denial is of course involved in their doctrine—but by going a step further, and holding that what we call our Reason, and are so proud of, is merely a bundle of Instincts, as some have termed it—a more acute and perfect degree of Instinct. Smellie, in his entertaining work on the Philosophy of Natural History, holds this opinion.—That is a book, by the way, much less esteemed than it deserves, even as a collection of facts and anecdotes; but I also think the honest printer (for such he was) had a good deal of the philosopher in him. I suppose, as the well-educated printers in the foreign university towns, and some of our own Oxford men, used to be critics and scholars, from the atmosphere of the place, so your Edinburgh printer, when well bred, is a metaphysician.

B. You are right as to Smellie at least, and I agree with you as to his book, though it is too long, and in parts loosely reasoned, as well as not over-accurate in his facts, according to what I have heard from naturalists. But he was a man of considerable merit; and lived a good deal in the literary and scientific circles of Edinburgh. I knew him, but slightly. He would have done much more had his habits been less convivial. But I rather fancy the somewhat pretending title of his book tended to make men disallow the merit which it unquestionably has.

A. But what do you hold of the dogma in question, and of which he is perhaps the most round asserter?

B. I entirely deny it; nor do I conceive that

any part of the subject is more free from all doubt than this, unless indeed we come to the question of liberty and necessity, and resolve the whole into a mere dispute about terms.

A. Liberty and necessity! preserve us!—I am taken by surprise. Why I had no idea that we could ever have got among those heights and clouds already—"apart set on a hill retired," and reasoning on "free-will," like the gentry more acute than amiable, who held their metaphysical disputations there.

B. Don't be alarmed—but the subjects in one single point do certainly touch. What I mean is this: if you say that, when a man reasons, one idea suggests another, and that he must follow the train, and can no more avoid drawing his conclusion, when he compares two ideas, than a bird can avoid building its nest in a particular fashion, or a bee can help making hexagonal cells, then you seem doubtless to liken Reason with Instinct. But this is true only on the supposition that a man's mind is mechanical, and that his faculties are placed beyond his control. Now, suppose it to be admitted that I cannot avoid drawing a certain conclusion from premises in mathematical matters—as that the three angles of a figure are equal to two right angles, if that figure have those three angles only—I am under no such necessity in any question of moral or probable evidence; and on a question like that different minds will differ, or the same mind at different times. Again, I am under no necessity—even if I admit that I have no choice on moral evidence—I am under *no necessity* of exercising my volition in one given way, unless indeed you deny that I have ever any free-will at all. If so, and if

you contend that, the same motives being presented to my volition in the same circumstances, I must needs choose the same course, you may also contend that, the same circumstances being presented to my judgment in the same frame of the feelings, I must needs draw the same conclusion; and this may seem to make out an identity of Reason with Instinct: but this is the dispute of liberty and necessity which every man's consciousness and hourly experience decides in favour of liberty, except in so far as it is a mere dispute about terms. But I really do think that, allowing the question to be disposed of either way, there is a specific difference between Reason and Instinct: for, even upon the principle of necessity, suppose the man and the bee to be equally under the entire control of the premises in reasoning, and the circumstances or motives in willing, whatever it is that each does, be it the necessary consequence of the circumstances or not, is different in the two cases. Suppose that if the bee reasoned she would be under the necessity of drawing the same conclusion, and that if she exercised an election, she could not avoid choosing one course, and that it is the same with the man—it still is not only not proved that the bee does reason or choose, while we know that the man does, but the contrary seems proved.

A. How so? Were I to maintain the contrary I should deny that we have any such proof. How do you prove the negative proposition, that the bee does not reason and will?

B. Observe, I do not say we have the proof of the negative as clearly as we have of the affirmative. But, beginning with laying aside those actions of animals which are either ambiguous or are refer-

able properly to reason, and which, almost all philosophers allow, show a glimmering of reason; and confining ourselves to what are purely instinctive, as the bee forming a hexagon without knowing what it is, or why she forms it; my proof of this not being reason, but something else, and something not only differing from reason in degree but in kind, is from a comparison of the facts—an examination of the phenomena in each case—in a word, from induction. I perceive a certain thing done by this insect, without any instruction, which we could not do without much instruction. I see her working most accurately without any experience, in that which we could only be able to do by the expertness gathered from much experience. I see her doing certain things which are manifestly to produce an effect she can know nothing about, for example, making a cell and furnishing it with carpets and with liquid, fit to hold and to cherish safely a tender grub, she never having seen any grub, and knowing nothing of course about grubs, or that any grub is ever to come, or that any such use, perhaps any use at all, is ever to be made of the work she is about. Indeed, I see another insect, the solitary wasp, bring a given number of small grubs and deposit them in a hole which she has made, over her egg, just grubs enough to maintain the worm that egg will produce when hatched —and yet this wasp never saw an egg produce a worm—nor ever saw a worm—nay, is to be dead long before the worm can be in existence—and moreover she never has in any way tasted or used these grubs, or used the hole she made, except for the prospective benefit of the unknown worm she is never to see. In all these cases, then, the ani-

mal works positively without knowledge, and in the dark. 'She also works without designing anything, and yet she works to a certain defined and important purpose. Lastly, she works to a perfection in her way, and yet she works without any teaching or experience. Now, in all this she differs entirely from man, who only works well, perhaps at all, after being taught—who works with knowledge of what he is about—and who works, intending and meaning, and, in a word, designing to do what he accomplishes. To all which may be added, though it is rather perhaps the consequence of this difference than a separate and substantive head of diversity, the animal works always uniformly and alike, and all his kind work alike—whereas no two men work alike, nor any man always, nay any two times alike. Of all this I cannot indeed be quite certain as I am of what passes within my own mind, because it is barely possible that the insect may have some plan or notion in her head implanted as the intelligent faculties are: all I know is the extreme improbability of it being so; and that I see facts, as her necessary ignorance of the existence and nature of her worm, and her working without experience, and I know that if I did the same things I should be acting without having learnt mathematics, and should be planning in ignorance of unborn issue; and I therefore draw my inference accordingly as to her proceedings.

A. Come, come, Master B., I begin to surround you and drive you from your original position, maintained both now and last summer, about the impossibility of defining. Have you not as nearly as possible been furnishing a definition? At least, are not the materials of definition brought together

which you deprecated, and would have us reserve to the last?

B. Patience, good man—patience! What is this to what you have gone through? Fancy yourself once more in the House of Commons, on the Treasury bench, listening to ——— ———

A. God forbid!

B. Or suppose yourself again in Downing Street, with Drummond announcing a succession of seven deputations or of seventeen suitors.

A. The bare possibility of it drives me wild. Why, to convert you to the most absurd doctrine I could fancy—to make you swallow all the Zoonomia whole, and believe that men derive their love of waving lines and admiration of finely-moulded forms from the habit of the infant in handling his mother's bosom, or even to drive you into a belief that the world was made by chance—would be an easy task compared to the persuading any one suitor at any one of the offices that you had any difficulty in giving him all he asks, or convincing any one of those seven deputations that there exists in the world another body but itself.

B. Or to convince any one man, who ever asked any one job to be done for him, that he had any one motive in his mind but the public good, to which he was sacrificing his private interest. I remember M. [Melbourne] once drolly observing, when I said no man could tell how base men are till he came into office, "On the contrary, I never before had such an opinion of human virtue; for I now find that no man ever drops the least hint of any motive but disinterestedness and self-denial—and all idea of gain, or advantage, is the only thing that none seem ever to dream of." But

now compose yourself to patience and discussion—take an extra pinch of snuff—walk about for five minutes, a distance of five yards and back, with your hands in your breeches' pockets, and then return to the question with the same calmness with which you would have listened to a man abusing you by the hour in Parliament, or with which you looked an hour ago, in the Castle farm, at the beast you had bred, and which by your complacent aspect I saw you had sold pretty well.

A. But, indeed, I sometimes can't help fancying that it may be as well to take our observations upon Instinct from the operations and habits of such large animals as him you speak of—at least, not from insects; because it is possible that if we could see as accurately all the detail of the latter as we do of the former, much of the marvellous might disappear, and we might be as well able to account for their proceedings, which now seem to us so unintelligible, as we are to account for those of the greater animals, which are clumsy and cumbrous enough, and rather appear to proceed from an obscure glimmering of reason than from an inexplicable power guiding them unconsciously to work with the perfection which we ascribe to the bee. In a word, might not the cells be found to have as many imperfections, as great deviations from the true form, as any of the ox's operations have from perfect exactness, if either the bee were as large as the ox, or our senses as acute as the bee's? Has she not as great aberrations from the exact pattern in proportion to her own size and to the instruments, her feet and feelers, which she works with? I throw this out as a matter very fit to be settled in the outset, in order that our

own reasoning may not proceed upon gratuitous assumption.

B. For the sake of ascertaining how far the working is as perfect as it appears, I admit the importance of your observation; but for nothing more. I deny that it affects the body of the argument at all; because that depends in no degree upon the perfection of the work. Thus the proceedings of the solitary wasp are just as good for my purpose as those of the bee. Nay, the instinctive operations of the greater animals furnish exactly the same materials for reasoning, though they may not be so striking. However, to the point of your comparison—you must keep in mind that we have applied the powers of the microscope to the operations of the bee. Now, without going to an instrument of the power of Torre's, which magnified the linear dimensions between 2000 and 3000 times, and consequently the surface above 6,000,000 of times, take the much more ordinary power of 400, which magnifies the surface 160,000-fold—nay, if you take a microscope of only a 90-times magnifying power, you will see the work of the bee in a straight line, exactly as you do that of a man with the naked eye. But, I need hardly add that, if you only saw it a quarter as well, or with a glass that magnified 20 times, it would be enough: for then you would examine it as you do the beaver's with your naked eye. But, further, all the difficulty you suggest proceeds upon a fallacy. The lines may not be exactly even which the bee forms; the surfaces may have inequalities to the bee's eye though to our sight they seem plane; and the angles, instead of being pointed, may be blunt or roundish: but the pro-

portions are the same; the equality of the sides is maintained, and the angles are of the same size; that is, the inclination of the planes is just—in other words, all the inequalities don't affect the proportions of the parts; for they are common to each thing compared with another; the axis running through the inequalities (to speak more rigorously) is in the true direction, and the junction of the two axes forms the angle of 60° as accurately as if there were no inequalities. Now, then, the bee places a plane in such a position, whatever be the roughness of its surface, that its inclination to another plane is the true one required.

A. I suppose it is so; but, at any rate, the solitary wasp carrying the grubs in proper number and placing them in the hole over the egg, or the bee placing her egg in the liquor at the bottom of the cell, and making that cell of the length to which the worm when hatched will grow—she having never seen either the worm or the chrysalis—is sufficient for our purpose.

B. Not to mention the operations of the worm itself in spinning the cocoon, and making it precisely the size required to line or carpet the cell when expanded and applied to it—nay, the motions of the chick in the egg, which always begins at the same place, and moves itself on in the same direction, chipping away till it effects its own liberation—all of which must be prior to experience, and without the possibility of teaching.

A. You desired me last summer to examine, with a view to the same point, the ducklings hatched under a hen, and then taking the water, without the possibility of her teaching. They

have the form, web-feet, &c., which enables them to swim, and which a chicken has not. Their manner of getting into the water I cannot say I well ascertained; but it is certain enough that the hen's proper brood would not have got in, and probably she would have succeeded in preventing them, though she might not be able to keep the ducklings out.

B. However, a more decisive case occurred to me afterwards: that of chickens hatched in the Egyptian ovens. I have lately seen an intelligent Bey and his aide-de-camp, who gave me the whole process; and, as was to be expected, there is not the slightest difference between the conduct and motions, and habits generally, of these chickens, and of such as are hatched and brought up by hens. This fact, as well as the working of the chrysalis in spinning the cocoon, and of the chick in chipping with its bill-scale, renders it quite unnecessary to inquire whether or not the honey-bee or social wasp work by instruction from other bees or wasps. That, however, appears to be impossible, when we consider that as many as 30,000 young insects come from one nest, to teach whom there are not old ones anything like enough; and to teach whom in a few hours, or even days, to work as exactly as themselves seems wholly impossible. The observation of cases where such teaching is impossible, as in the chrysalis and unhatched chicken, at once removes all doubt, and precludes the possibility of supposing that the wasp's and the bee's architecture can be traditional, or handed down by teaching, from the first insects of the species that were created. Henceforward, therefore, we must assume as part of the fact that

the cells of the bee are made without any instruction or any experience, and are as perfect at first as they ever are; which, by the way, explains another peculiarity of instinct—that it never improves in the progress of time. The bee, 6000 years ago, made its cells as accurately, and the wasp its paper as perfectly, as they now do.

A. Let us advert to one thing more, and, having settled it, the way may at least be said to be cleared for the argument, perhaps somewhat of progress even to be made in the inquiry. You have been speaking of Instincts in the plural; of course you do not mean to be taken literally, as admitting more kinds of mental Instinct than one.

B. Certainly not; any more than when speaking of the mental faculties I admit of more minds than one, or more parts than one of a single mind. This last form of speech has been so used, or rather abused, especially by the philosophers of the Scottish school, accurate and strict as they for the most part are, that they seem to treat the mind as divided into compartments, and to represent its faculties as so many members, like the parts of the body. But it is one thing or being perceiving, comparing, recollecting—not a being of parts, whereof perception is one, reasoning another, and recollection a third; so Instinct is one and indivisible, whatever we may hold it to be in its nature, or from whatever origin we may derive it. This thing, or being, is variously applied, and operates variously. There are not different Instincts, as of building, of collecting food for future worms, of emigrating to better climates—but one Instinct, which is variously employed or directed. I agree with you, however, that we have now done

something more than merely clearing away the ground. We have taken a first step, or, if you will, laid a foundation. We have ascertained the peculiar or distinctive quality of Instinct, and that which distinguishes it from Reason. It acts without teaching, either from others, that is, instruction, or from the animal itself, that is, experience. This is generally given as the definition or description of Instinct. But we have added another peculiarity, which seems also a necessary part of the description—it acts without knowledge of consequences—it acts blindly, and accomplishes a purpose of which the animal is ignorant.

A. I pause here and doubt of this addition. I perfectly admit the fact that it produces an effect, manifestly the object of its operation, and yet without knowing it, consequently without intending it or designing it. But there seems reason to think that it always intends to produce some one effect, and does produce it—that it has some one purpose, and accomplishes it, and so designs something which it does. Thus animals are impelled by hunger to eat; their eating produces chyle, blood, and all that is secreted from the blood; yet they had no design to promote their own growth and preserve their own life. At least they ate long before they had any such design or any knowledge that such would be the consequence of gratifying hunger. So of continuing their species. May not the solitary wasp, for instance, have its organs and its senses so constructed as to receive an immediate gratification from collecting and burying grubs? If so, her knowledge extended to one, the first, event, and she had the design in view of producing this event; though wholly

ignorant of any subsequent event. The desire of the first event, the fact of that event being a gratification to the insect, was the means taken by the Creator of the insect for making her do that which was to produce the important consequence, forming the real object in view, though concealed from the animal. Thus we may conceive that the insect is endowed with an appetite for carrying grubs, and that this is so adjusted in point of intensity as to be satiated when just so many grubs are transported as will feed the next season's worm, which is endowed with the desire to eat these grubs, rejected as food by the parent insect. So the wasp's senses may make the flavour, or the smell (for that seems all she enjoys), of a living caterpillar more grateful than of a dead one; and hence she takes those that will keep sweet till her own grub is hatched.

B. I do not deny the possibility of all this; although there seems something gratuitous in it, and we possibly never can know the truth by any observations or experiments. I shall presently show why I do not think it would entitle us to erase this ignorance of what you would call the second event, or the object of the secondary design, from our list of the characteristics of Instinct. But in the meantime I will mention what occurs to me on your objection in point of fact. The instant that a solitary wasp is hatched, or a bee can fly, away they go to the spot where the caterpillars or the wax-yielding substances are to be found. What guides them through the air to things they cannot descry or do not know the use of?

A. It costs me no more to suppose that there is some smell or other sensation to guide them—some

odour, for example, which penetrates the air, and being grateful to them makes them desire to approach the odoriferous body. Thus the bee smells the nectary of flowers; she flies to them, she sips, and the wax is secreted in her stomach. I grant you that I have more difficulty with her operation in using it.

B. You clearly have; for what should be the special gratification of that? We are admitting that she has no kind of knowledge that the cell is to be used in hatching and rearing the brood, any more than that an hexagonal figure, with a certain inclination of its rhomboidal bottom, is to enable her and her associates to employ the space and the wax in the way of all others most economical of room and work and materials; and so as just to accommodate the size of the unknown and unseen worm, chrysalis, or young bee, and no more—and also to suit its form.

A. I think I could suppose also in this case that her desire of action—her love of motion—is gratified by the operation, and is satiated by continuing that motion to a certain extent, where she stops.

B. But allowing your right to make all these suppositions equally gratuitous, one after another, and to extend them as the argument proceeds, and to relieve the pressure as the fact pinches—see what it is that you must assume. The comb is constructed thus. Wax-making bees bring a small mass of this material and place it vertically to the plane from which the comb is to hang down. Then other bees begin to excavate, one on one side, another on the other, and they work with such perfect nicety, as never to penetrate through the thin layer of wax; also so equally that the

plate is of equal thickness all throughout, its surfaces being parallel. You must, therefore, suppose some repugnance at once to a plate ever so little thicker, and to one ever so little thinner than the plate's given thickness. Indeed, this supposition, which some naturalists have made, is wholly unsatisfactory, and shows no accurate regard to the facts any more than their notion (a most crude one) that the hexagon cells arise from so many cylinders pressing on each other. The supposed instinct not to perforate wax, but to draw back when they come to a given thickness, is inconsistent with the fact; for the original plate they work on is uneven and of different thicknesses on both sides, and there is no bee in the world that ever made cylindrical cells. Huber has distinctly shown, from having observed them at their work, that they make them in quite another way; nor indeed, if they did, could any pressure ever produce hexagons, and far less rhomboidal plates. The wax-worker's bringing plates of a given thickness is also wholly incapable of accounting for the angles, that is, the inclination of the plates—for supposing the bee to make a groove (as she does), and suppose she has some means of bisecting its arc by two chords, this only, with the thickness of the cake, would determine the depth of the rhomboid, and that can be easily shown not to be the rhomboid actually made. She therefore makes angles wholly independent of the thickness, not to mention that were we to admit that the cake's thickness governs the whole, we do not solve the problem; the difficulty is only removed a step; for then how is that exact thickness obtained? But this will not do even to that extent; a great deal more is done by the bee, and a

great deal more must be supposed to make it conceivable that she has any immediate or primary intention. She works so that the rhomboidal plate may have one particular diameter and no other, and always the same length, and that its four angles may be always the same, the opposite ones equal to each other, but each two of different quantity from the other two; and then she inclines the plates at given angles to one another. Why is there such a gratification to the bee in a straight line—in a straight line at right angles to a plane—in rhomboids—in rhomboids with certain angles—any more than in lines or planes inclining at other angles to one another? Why is the bee, after working for half a quarter of a line in one direction, to go on, and not take delight in a change of direction? If she goes on, why is she to be pleased with stopping at one particular point? Nay, why is each bee to take delight in its own little part of the combined operation? Why is each to derive pleasure from doing exactly as much as is wanted, and in the direction wanted, in order that when added to what others have before done, and increased by what others are afterwards to do, a given effect, wholly unknown to her and to all the rest, her coadjutors, may be produced?

A. It certainly is difficult to say. I can barely imagine the different bees so formed that some inexplicable gratification may be the consequence of moving in one line, and making one angle, and that any other line or angle whatever may be disagreeable to them. The concert in the operation of animals seems to increase this difficulty much, always supposing there is real concert without any arrangement, communication, or knowledge. No

man ever acted so as to make his operations chime in with another's, unless he either had previous concert with that other, or both acted under a common superior, and obeyed his direction; and then the joint operation was that of this superior. But suppose a man were compelled by some feeling he could not account for, and did not at all understand, to go at a given time, to a certain place, and with such speed as to arrive there at a given moment, and were to find another just arrived there, who came to meet him without the former previously knowing of this,—we should have a case similar to that of animals acting in concert, supposing them to do so. There is, however, some doubt of this as to the bees; for Huber has said that they all act in succession rather than co-operate contemporaneously.

B. I really can see no difference that this makes in the argument as to concert. One bee brings wax and does not sculpture; another sculptures and does not bring wax: but the wax-worker brings just as much as the sculpturing bee wants, and at the very time she wants it; also, one works on the face, and another on the back of the same rhomboidal plate; and all so work as never to interfere with or jostle one another, which is the perfection of concert, and can only among men be effected by discipline, which refers the whole of the different purposes to one superintendent, and makes his unity of design the guiding rule and impulse, because concert among the different agents is otherwise unattainable. But I own I can see no greater difficulty thrown in our way by concert than by blind agency—supposing it blind as to both the events, and not merely blind as to the secondary consequence—and your suppo-

sition of a first event known and designed, the secondary being hidden from the animal, would, I think, account for a case of concert, as much as for any other operation; for your hypothesis of sensations and impulses would apply to concert. You might say that each bee was induced by the gratification of doing a certain thing, to take a certain line at such a time; that what it did should answer to what some other bee was by the like means induced to do at the same time. I see no difference in the two applications of this hypothesis.

A. I rather think the time makes some difference; at least in rendering an addition to the hypothesis necessary. For though the gratification of bringing the caterpillars to its nest will account for the solitary wasp doing what is also to serve the purpose of feeding its young next season, something more is required than this motive to make one bee act in concert with another; it is necessary that there should be a gratification, not only in doing the thing required, but in doing it at the very moment required; so that both bees must be supposed to feel at the very same instant of time the desire of the gratification in question, and yet without any concert or communication. I hardly see how my supposition of sensations and pleasures or pains will explain this.

B. I all along have seen the greatest difficulty in your explanation; but does this consideration of time increase it materially?—or rather, is it not in all cases part of the riddle which instinctive operations present to us? Thus the solitary wasp acts, that is, according to your hypothesis, feels the given sensation or derives the supposed gratification at such precise time that her acting upon it will suit

the time required for the birth and growth of the worm. The bird breeds,—but before laying her eggs, and without any knowledge when she is to lay them, makes her nest, and it is ready at the very time required. Therefore she feels the desire of nest-making at the proper moment. I will admit, however, that there is something still more extraordinary in two separate and independent insects feeling the same impulse at the same moment; and the difficulty is incalculably augmented, if twenty or thirty insects all have the impulse separately, but all at once, so as to act together. Indeed, I cannot help regarding your solution as not only a gratuitous hypothesis, for that it must needs be from the nature of the thing, but one hardly conceivable, and in truth as difficult to suppose possible as any other thing which we can fancy in order to explain the phenomenon—for instance, some invisible power or influence acting upon the animal, or upon the different animals at once. This is not at all more gratuitous, and it more easily explains the phenomenon.

A. Consider if there is really any such essential difference between the case of instinct which we have been considering, and any of the best known operations of men, as well as animals, where we are not wont to speak of instinct at all. Thus men eat from hunger, which they intend to satisfy; but the consequential effect, not intended, is chylification, sanguification, secretion, and growth or sustentation of the body, as well as the effect intended, and immediately produced, of satisfying hunger. The mother eats things which satisfy her appetite, and that is all she cares for; but these things also produce milk, which nourishes

her infant, and that she never thought of. The time is also suited by the feeling. The hunger gives the supply when the system wants it; the eating produces the milk when the infant requires it. How does this differ from the other case?

B. Much every way. The difference is wide and marked. In the cases you put, the mental instinct is confined to produce the effect intended; and having produced it, the mind stops there and does nothing more. The powers of matter, its physical qualities, set in motion, do the rest, of course beyond our direct control, and unaided by us as unknown to us. But in the case of Instinct the mind performs both parts—both the things which it knows and intends, and the thing which it neither knows nor intends. The mother eats—nature produces the milk without the least action of hers. But the bee not only gratifies herself (if that is the cause of her architecture) by the structure of the cell, but by her art, by her work, she does the other thing also, that of providing a lodging for her young. It is as if the mother in your supposed case were both to eat intentionally for satisfying her hunger, and at the same time, without knowing or intending it, were to make milk by some process of internal churning. It is as if in eating we at once chewed and swallowed, and also with our tongue or teeth or fingers made chyme, and then chyle, and then blood. It is as if the animal in pairing both gratified his sexual passion and voluntarily made the young by some process of manipulation, though without knowing what he was about, or intending to do it.

A. You must here distinguish a little, or rather you must take into your account a point of resem-

blance which you are passing over. How can any *one even acting with design affect matter in fashioning it* or *moulding it*, except by *availing himself of* the powers, mechanical or chemical, belonging to matter? If I distil, it is by availing myself of the process of fermentation and of evaporation, and of condensation. If I sow and reap, it is by availing myself of the prolific powers of heat and moisture in the process of vegetation. So even in processes where I seem to do more and nature to do less; if I build, or carve, or weave, it is by availing myself of the qualities of cohesion and gravitation, and of the powers of the wedge in hewing, or of friction in polishing. Do not the animals who eat, the mothers who give suck after eating and thereby secreting milk, in like manner do part themselves, and as to the rest avail themselves of the powers of nature in chylification, sanguification, and secretion? You perceive how much more nearly akin the cases are than you have stated.

B. I am well aware of it; indeed, we are now coming nearly into the controversy about productive labour, which you and I have often amused ourselves with as political economists; when I have always held that it was a far less easy thing than those who discussed the metaphysical parts of that science supposed, to draw the line between productive and unproductive labour, either by including manufactures or only commerce in the latter—and agriculture alone or with manufactures in the former, the productive class. Be it so: I am content, if there be as marked a distinction here as between the labour which produces or moulds matter into a new substance, and that which only exchanges one thing for another; or defends the community, or

administers justice among its members. But, in truth, we have, in our present argument, a specific difference, admitting all that you have urged, as to the affections and properties of matter being used by the animal in both processes. The great and broad difference is this. In the one case, as in the wasp carrying the caterpillar to its nest, which she does and means to do, or, if you will, gratifying her senses with the carrying, whatever instruments she works with, she does the thing knowingly and intentionally; she does it by means of gravitation and cohesion, but still it is she, her action, her will, her mind that does it. In the other case, that of leaving the caterpillar in the nest for months, she has done; she quits the work; nothing she does is at all conducive to the operation then performed by nature; but what she did was all that could be done excepting by nature. So the mother eats the galactigenous matter, and then has done; nature does all the rest. But there is this material difference in what the bee or the wasp does,—that she finishes the whole operation voluntarily; it is as if the mother were not only to become gravid, but to prepare the child's clothes and habitation herself, and yet to do this without knowing what she was about, and while she intended to do, and thought she was only doing, some perfectly different thing. If, indeed, you put the case of a person ploughing and sowing for the purpose of strengthening his limbs or amusing himself, and not meaning anything to grow, and also ignorant that anything will grow, and yet choosing the seed which will grow, and sowing it at the right time to make it grow— then you merely put the case of Instinct in other words; and the one thing will be as difficult to

explain as the other. And if one man should, by mere blind chance, do this the first time, and some other man, equally ignorant of what the use of thrashed wheat was, should reap and thrash it, and garner it away—and if all men were to do so in two bodies, equally ignorant of what they were about, and yet both chiming in with each other in their operations, and both agreeing with the nature of things, then we should say this is the self-same case with Instinct—but we should add that this could not happen without some overruling power not only giving those men the desire to stretch their limbs, but guiding them immediately how to do it—for there, as here, two designs and only one designer appears, and therefore some non-apparent contriver must exist and work. We may again put it thus—When a man brews or tills, he does something himself, and leaves the rest to the powers of nature. So when a mother eats or drinks to gratify hunger or thirst, she has done; nature does the rest, namely, supports her body and secretes the milk for her young. But the bee or the wasp does the whole. They use the powers of matter, indeed, as the farmer and brewer do, and as the mother does, in the operation itself performed by them, namely, breaking the ground, throwing the seed, steeping the grain, eating the victuals—but the insects finish the operation, and leave nothing to be done. The solitary wasp has completed a cell and provided food; the young have only to eat it. The bee has completed a cell with food likewise. Neither mind nor matter on the part of either insect has anything more to do; the thing they intended and knew all about is done, and in doing that thing they did something else neither

known to nor intended by them. They only used the powers of matter in doing the thing they intended. They did not leave any natural powers to do the other thing not intended by them; but they did it also, though unintentionally. Man does what he intended, but he does nothing more—nature does the rest, both where he intended it, as in ploughing or brewing, and where he did not, as after eating to satisfy his hunger. In the bee it is like a whole manufacture completed by the animal, though unintentionally; as if a man were to make a skein of fine lace while he only meant to amuse himself with twirling the bobbins, or playing with his fingers among the flax or the threads.

A. I certainly think we do get to something like a specific difference. But compare the work of the insect with certain chemical processes. If you mix, or if any natural process mixes, certain salts, and the liquor is left to evaporate, there are formed crystals, say hexagons, as accurately as the bee forms her cells. Also certain bodies move in lines which have properties similar to the angles in the comb, as a heavy body falling through the shortest of all lines. There is no doubt a difference here, and a marked one; yet it is as well to consider it.

B. Doubtless there is a difference, and the greatest possible. These forms are assumed, and these motions performed: for instance, a stone falling to the ground in the shortest line, or the planets, all arranged respecting their masses, the direction of their motions, and the inclinations of the planes they move in, so as, according to Laplace's beautiful theorem, to preserve the system of the universe steady, by affixing limits, maxima and minima, between which the irregularities os-

cillate; all those things are the direct and uninterrupted agency of the property which the Deity has impressed on matter at its creation; perhaps, of the laws which His power perpetually maintains. But they are wholly unconnected with any animal workmanship of any kind; they have no subordinate mind to guide them; nor can any act of ours, or of any animal, affect them. On the contrary, in all our operations we must conform to them.

A. Unquestionably it is so; and this is the distinction, and the broad one. But then it follows from the preceding deductions, that we must consider in the works of Instinct the animal acting as an agent, though ignorantly and unintentionally,—a tool or instrument blindly used to do a certain thing without its own knowledge or design; and the tool being a living thing, the mind is the instrument. In the case of matter, the matter is the instrument blindly serving the purpose by obeying the physical law. In our case the mind is the instrument, and obeys the mental law as perfectly and as blindly.

B. There is one thing, however, always to be considered. We have hitherto been viewing Instinct alone, and arguing as if animals always acted by it, and never otherwise. Now this is quite impossible, at least in the sense in which we have taken the word Instinct. There may be some doubt if we are right in so limiting the term, though I have a very clear opinion that we are. Paley and all or almost all others define Instinct to be a disposition or acting prior to experience, and independent of instruction. But among other objections, there is this one to the definition, that

it amounts to saying "an acting without knowledge," and yet does not say it. There may be no experience, and yet no Instinct, *e.g.*, we may act on the information of others—but then what shall be said of the information given by reasoning; that is, by our inferences from our own thoughts? This is plainly not instruction. Is it experience? If so, the definition seems only to say, that Instinct is anything that is not reason, in other words, that Instinct is Instinct. But I apprehend, when we speak of instinctive operations we always have an eye to some end which is blindly served by the act—some act done by the animal, in which he does what he does not mean, and in doing which he is a blind instrument.

A. How is it when we speak of instinctive desires?

B. I should say we then mean something different from merely animal or natural desires, for that would make every thing instinctive. We mean desires which are subservient to some purpose towards which they move: some end beyond the doing the act seems always involved in our notion of Instinct. We do not call mere moving, yawning, stretching, instinctive; and when we speak of sucking or eating, and the desire or power to suck or eat, as instinctive, it is surely with a regard to the subserviency of those operations to support life that we so term them. If they did nothing for our frame, we might call them natural, hardly instinctive.

A. But be this as it may, no one can doubt that animals, if we allow them to have these Instincts, and to act for ends unknown to themselves, have other actions of a kind resembling our own, and

quite distinguishable from what we have been calling Instincts; therefore it signifies little whether or not we are right in giving the name to actions accomplishing undesigned and unknown purposes. provided we keep that definition in view. These animals also have other actions, where they both know and intend and accomplish their definite object.

B. Undoubtedly, they have many such in which their operations of mind and body cannot be distinguished from our own. Now whether these are under the guidance of faculties like ours; whether they have reason; whether they have faculties differing from our own in kind, or only in degree —we need not at present stop to inquire. It is quite enough for us that they have two kinds of operations, one which we agree to call Instinctive, distinguished by the ignorance of the object and want of intention; the other both knowingly and intentionally done: so man, acting almost always rationally, also acts in some rare cases unintentionally—chiefly in early infancy.

A. There may be instinctive acts with knowledge, and there may be acts not instinctive without knowledge. Does not this break in upon the definition which excludes knowledge as well as design? Many parts of human conduct seem to be guided by Instinct, and yet with knowledge.

B. This would no doubt overturn the definition, provided it be clear that "*knowledge*," and the "*presence of knowledge*," are here used in the same sense as in that definition. But we must make a distinction. There is a knowledge of some *end* or *object* in view, and a knowledge of the *means* whereby that end or object is to be attained;

in other words, of the *mode* of *operating*—of the *process*. There is also a distinction to be taken between instinctive *desires* and instinctive *operations*. The objection you have now made refers to the former—to desires; the latter, the operations, are chiefly referable to the great question respecting the controlling mind, or actual interposition of the Deity, to which we are approaching; but it also refers, in some measure, to the objection which you raise. Knowledge of consequence comes within the description of object or end; and if there be no intention to attain an end actually pursued, there can be no knowledge of it; and conversely, if there be no knowledge of it, there can be no intention to attain it. Take any instance of what you call human instinct, as hunger, or the sexual passion—these are desires, and their gratification may be pursued without any knowledge of, and consequently without any view to, the consequences of making chyle and blood to support the individual, or offspring to continue the race. As far as the mere gratification of the desire or supplying of the want goes, we may be said both to know what we are doing and to intend or mean to do it. We are attracted by our senses, that is, by the effect of our senses on our minds, to do certain things; and this is called instinctive acting,—I apprehend incorrectly. It is *natural* desire, but why instinctive? When we say Instinct, do we not mean something beyond this? Desires may be subservient to Instincts; but are they all we mean by Instinct? They may lead to the attainment of a certain end; they may be the way in which Instincts operate: but are they themselves Instincts? If two foods are presented

to an animal, a man for example, who knows nothing of either; and he is impelled, without knowing why, to take the one and reject the other, and the one is wholesome and the other a poison; we at once call this the operation of instinct, which some define to be knowledge without instruction or experience, but which I have wished rather to call mental action without knowledge, or at least independent of knowledge. So in Galen's beautiful experiment on the kid just born, having been taken out of the mother, and which of course had never sucked, when, upon many shallow pans with different liquids being placed near it, the animal preferred at once the pan containing goat's milk. If the reason for the preference is some greater gratification of the senses, or that the one food is pleasing, for instance, in smell fragrant, and the other offensive, this may be the mode taken by nature to make Instinct operate according to your former hypothesis, which we have been discussing at large; and we certainly cannot tell that such may not, in all cases, be the mode taken by nature for working to the same end. It seems, however, eminently unlikely that the whole operations of bees, for example, should be owing to the pleasure their senses receive from one particular form and proportion alone, and a repugnance to all others, because of their being disagreeable to those senses. But do we not, in all cases, mean, by using the word Instinct, to point out the unknown connexion between the thing done and something else of which the animal—the agent—is not aware? I grant you that we speak of Instinct of hunger and Instinct of sex; but is not this only a way of saying, and do we not mean, merely desire of

food or sex, the gratification of which is a natural propensity, and known and felt by us to be such? Thus it is an Instinct which makes animals propagate their kind while they merely mean to gratify their passions, and which enables them to prepare a nest, and have it quite ready at the very time they are to want it for laying their eggs in. We always seem to have the *motive*, the *end*, and the *blind instrumentality* in our view when we speak correctly of Instinct. I may intend to do a thing, and know both the object in view and that portion of the operation or process which depends on me—*e. g.*, to eat for the purpose of making chyle. My ignorance of that process, with which I have nothing to do, would not make the operation of mine be called an Instinct. Indeed, even if I eat to satisfy hunger, without any design of supporting the system, this act is not instinctive, except in so far as doing and meaning one thing, I am doing another thing ignorantly and unintentionally.

A. I think we have got as far as we can in these preliminary discussions and observations of Facts, and may now proceed to Theorize and infer.

B. However, we are come, or coming, to a part of the subject where we should be among our books; for we shall now have to look at them in proceeding further. At least, it is as well we should observe what has been held on this matter by philosophers. So we had better adjourn for the present; and resume our conversation in the library, if indeed you, who are accustomed to Althorp and Spencer House, can condescend to call anything in this part of the world by that

name. We commonly, from feeling this modesty, name it the Book-room.

A. And I dare swear, also from your love of the Saxon idiom.

B. Possibly; though I would that our good old English never suffered more havoc than by calling Book-rooms Libraries. I expect to outlive it, as Serjeant Maynard said he had nearly done the law, with the lawyers.

BOOK OR DIALOGUE II.

INSTINCT.—(THEORY.)

HAVING thus far carried on our discussion in the open air, we removed, towards the afternoon, to the library—"cum satis ambulatum videretur, tum in bibliothecâ assedimus"*—and there conveniently pursued the subject, which greatly interested us both.

B. The manifest difference between Instinct and Reason which we have been observing, and its regular and constant action, always the same, and never improved, but never different, indeed apparently incapable of improvement, was probably the consideration which induced Descartes to consider animals as machines.

A. I am aware that this is commonly said of him. But I know not how that great man could really have held so untenable a position. Did he really consider them as mechanical contrivances—as mere physical substances, without anything answering to what we call Mind?

B. He is always so represented; but when you examine his own statement closely, you really find that this is an exaggeration, and that his doctrine

* "When we thought we had walked long enough, we took our seats in the library."—Cic. de Div. ii.

differs not very much from that commonly received. As has oftentimes happened to others, his sentiments are rather taken from the statement of them by those who were controverting them, than from his own words.

A. Where are they to be found?

B. Look here—you have them in the short treatise on Method, the introduction to his work on Dioptrics and Meteors. He dwells on brutes having no gift of speech, which yet requires very little reason, he says; and therefore he concludes not that they are less rational than man, "sed plane esse rationis expertia." * Thus far no doubt can exist; he only gives a very common opinion on the subject, though an opinion controverted by some, as I shall hereafter ask you to discuss: but it forms a head distinct from our present inquiry. But a little way further on he proceeds to illustrate his position in a manner which has given rise to the notion in question. "They do many things even better than ourselves," he says, "but this does not prove them to be endowed with reason, for this would prove them to have more reason than we have, and that they should excel us in all other things also—but it rather proves them to be void of reason, and that nature acts in them according to the disposition of their members, as we see a clock, which is only composed of wheels and

* De Methodo, 36.—"Istud autem non tantum indicat bruta minore vi pollere quam homines, sed illa plane esse rationis expertia. Videmus enim exiguâ admodum opus esse ad loquendum."

(Of Method, 36.—"But that not only indicates that brutes have less power than men; it also proves them to be void of reason. For we see that very little reason is required to enable men to speak.")

weights, can measure time better than we can with all our skill." He goes on to show that the interests of virtue are greatly injured by the belief, not that brutes have souls, but that they have souls like our own—"brutorum animam ejusdem esse cum nostrâ naturæ,"—and that therefore we have nothing more to hope or fear in a future state than flies or ants; whereas he had shown our souls to be by their nature independent of the body, and therefore not mortal like and with it. All this you perceive is anything rather than the doctrine that brutes are mere machines.

A. But where do you find the adversary's representation of it which you mentioned?

B. Here, in this other and very curious volume, containing his Correspondence with many learned persons, and some less learned, as Christina, Queen of Sweden, and our Princess Elizabeth, the Electress Palatine and stock of our present Royal family, to whom he writes, among other letters, one on her brother Charles the First's execution—which, to console her, he praises as more glorious than an ordinary death—"pulchrior, felicior, et dulcior."*

A. Does the Princess enter on the question of animals?

B. No; she seems to have been ailing with fever, and having been light-headed, she applies to the philosopher to explain to her how in the night she felt an irresistible desire to make verses: this he courteously explains (after saying it reminded him of a similar anecdote related by Plato, of Socrates), that it is owing to the agitation of the animal spirits, which in weak brains produces

* "Finer, happier, sweeter."—Epist. Pars I., Ep. xxvii.

madness, but in strong ones only a genial warmth, leading to poesy, and thereupon he holds her Serene Highness's case to be "ingenii solidioris et sublimioris indicium."*

A. Upon my word, I shall begin to think a person who could thus theorize as well as flatter about animal spirits and Serene Highnesses, was capable of shutting his eyes to the most ordinary facts, and believing brutes to be machines.

B. Do not undervalue this great man: he is the true author of all the modern discoveries in mathematics. He made the greatest step that ever man made since the discovery of algebra, which is lost in the obscurity of remote ages: I mean his application of algebra to geometry, the source of all that is most valuable and sublime in the stricter sciences and in natural philosophy. But assuredly his physical and psychological speculations are much less happy; although it was no mean fame to be the author of a treatise, the answer to which was the first work ever composed by man—Newton's Principia. But I was coming to the controversy on Instinct. An ingenious clergyman of Cambridge, Henry More, objected to the doctrine of the great philosopher, as laid down in that treatise to which we have been referring, on Method; and he began by describing the doctrine as denying sense and life to brutes. He speaks of Descartes's genius, "chalybis instar rigidum et crudele, quod uno quasi ictû omnium ferme animantium genus vitâ ausit sensûque spoliare in marmora atque machinas vertendo."† This he repeats in various

* "The proof of a more solid and more lofty understanding."

† "Rigid and heartless like steel, which, as by a single

ways, and argues against, as the doctrine of Descartes.

A. Nothing in what we have read out of Descartes' own writings justifies this. Is there any other passage to which More can allude?

B. He refers expressly to the passage in the "Tractatus de Methodo," and discusses the argument there given from the want of speech. But there remains a letter of Descartes to a certain great personage (ad Magnatem quendam), in which he repeats the doctrine of the treatise at somewhat greater length, but using the same comparison of a clock, and using it as a comparison. His whole contention is, that they, the brutes, have not reason like us, which he terms sometimes "intellect," or thought—"intellectum vel cogitationem." But that he means reason, and does not mean to assert that brutes are machines, seems plain from this, that in the same passage he allows them natural cunning, or craft, as well as strength—"imo et puto nonnullos (animantes) esse posse quæ naturalibus astutiis instructæ sunt quibus homines etiam astutissimos decipiant."* This is anything rather than describing them as mere machines.†

stroke, can deprive almost all animals of life and sensation, turning them into marbles and machines."—Epist. Pars I., Ep. lxvi.

* "Nay, I also think there may exist some brutes endowed with natural cunning to deceive the most cunning of men."—Epist. Pars I., p. 107.

† He afterwards, in the same letter, says, that although brutes do nothing to show they can think, yet it may by some be supposed that as they have limbs like our own, so thought (cogitatio) may be joined with those limbs, as we know it is with our own, although in them the thinking principle (cogitatio) may be less perfect than in us. "Ad quod," says he, "nihil est quod respondeam nisi quod si illa

A. But what does Descartes reply to his correspondent's letter, in which he represents that to be his doctrine? Does he object to Mr. More's statement?

B. Why, singularly enough, he does not in distinct terms repudiate it, though this may be owing to his supposing that, as he had used the comparison of the clock, Mr. More is also speaking in the same terms, especially as Mr. More had professedly used figurative language, and spoken of Descartes' cutting off all animals as with a sword. But he speaks certainly in this answer* more strongly than elsewhere. "I have diligently inquired," says he, "whether all the motions of animals came from two principles, or only from one; and as I find it clear that they arise from that principle alone which is corporeal and mechanical, I can by no means allow them to have a thinking soul. Nor am I at all hindered in this conclusion by the cunning and sagacity of foxes and dogs, nor by those actions done by animals from lust, hunger, or fear; for I profess to be able easily to explain all these things by the sole conformation of their limbs." He adds, that though he sees no proof of the affirmative proposition (of their having a thinking principle), yet he also admits there is no proof of the negative; and he then comes back to his favourite topic of its "being less likely that worms should have immortal souls, than that they should

cogitant ut nos, animam etiam ut et nos immortalem habent, quod non est verisimile;" ("To which I can only answer, that if they think as we do, they must also have, like us, an immortal soul, which is not probable;") and he proceeds to say, that oysters, sponges, and other imperfect animals, can hardly be supposed immortal.

* Pars I. Ep. lxvii.

move like machines;" and again refers to the want of speech.

A. How any man who ever saw dogs in a field pointing, or greyhounds chasing a hare, or still more, dogs sleeping and manifestly dreaming without any external object to excite their senses or motions, or who had observed birds taught tunes, could ever suppose them mere corporeal or material mechanism, things made of dead matter and without life, I cannot comprehend.

B. The best of it is that he positively affirms they have life. The letter I have just been reading from, and in which his doctrine, if anywhere, is stated the most explicitly, concludes by warning Mr. More not to suppose he denies them life; and it is remarkable that he uses the very words *vita* and *sensus*, which Mr. More had represented him as refusing to brutes—"Velim tamen notari me loqui de cogitatione, non de vitâ vel sensû. Vitam enim nullo animali denego."*

A. Then what does he mean by life and sense?

B. He goes on to tell you, "utpote quam in solo cordis calore consistere statuo;" mistaking the indication or effect of life for life itself. He adds, "nec denego etiam sensum, quâtenus ab organo corporis pendet."† Now, can it be that Descartes really supposed he had taken a tenable distinction here between mind in man and in brutes? Or that there could be any perceptible difference between a machine endowed with life and sensation, and

* "I would have it borne in mind, however, that I am speaking of thought, not of life or sensation, for life I deny to no animal."

† "Nor do I deny them sensation, in so far as that depends upon the organs of the body."

capable of imitation, of learning, and of much cunning—and a body animated by a mind? To speak of sensation as depending upon the corporeal organs is either unintelligible or it is a begging of the question, and the very same definition might be given of our own sensation—nay, is given of it by the materialists, who hold our mind to be the mere result of a physical organization. Yet with these Descartes differs more indeed than with all others.

A. I cannot help thinking, on the whole, that it is very possible this great man may have only meant to deny the brutes a reason, or mind like ours, a power of ratiocination, and not to consider them as mere machines. But I am clear of one thing, that if he did mean the latter, a more untenable doctrine never was broached upon this, or indeed upon any other subject.

B. We may therefore, I conceive, pass over this theory altogether. But another and a greater man has been so pressed with the difficulties of the subject, that he has recourse to a very different supposition, and instead of holding the Deity to have created brutes as machines without any mind at all, he considers their whole actions as the constant, direct, and immediate operation of the Deity himself. Such is the doctrine of Sir Isaac Newton, which is saying enough to prevent any one from hastily rejecting it, or rashly forming his opinion against it.

A. Does he not mean merely to derive the actions of brutes from a perpetually superintending and sustaining power of the Deity, as we ascribe the motions of the heavenly bodies to the same constantly existing influence? He probably only means that the brute mind, having been created, is

as much under the Divine governance, as the material powers, qualities, and motions are: in other words, that mind was created, and matter was created; and that still the actions and passions of both are constantly under the guidance of the Creator. So that Sir Isaac Newton would no more deny the separate existence of the minds of brutes, than he would the separate existence of their bodies, or of the heavenly bodies.

B. Here are his own words. The passage occurs in the famous 31st Query, or General Scholium to the Optics;* and you see that, after recounting the structure of animal bodies as proofs of design, he adds, "And the instinct of brutes and insects can be the effect of nothing else than the wisdom and skill of a powerful, ever-living agent, who, being in all places, is more able by his will to move the bodies within his boundless uniform sensorium, and thereby to form and reform the parts of the universe, than we are by our will to move the parts of our bodies." He proceeds to guard the reader against a supposition of the Deity being the soul of the world, or of brutes, or of His being composed of members or parts, stating that He only "governs and guides all matter by his prevailing power and will." So that you see he draws the distinction between the

* There is nothing more admirable for extent and generalisation of view than this 31st Query. The happy conjecture respecting the nature of the diamond in the 2nd Book (Part II., Prop. 10), does not surpass the wonderful sentence in the query, where Sir Isaac Newton classes together, as similar operations, respiration, oxydation, and combustion. These have since been discovered to be the same process. In Sir Isaac Newton's time, their diversity seemed as great as that between the diamond and charcoal.

mind or will of men, which influences the motions of their bodies, and the influence which moves brutes; plainly enough referring the latter to the Deity himself, as the *primum mobile*, or actuating principle; for he allows that the kind of ubiquity or universal action to which you refer applies to our bodies, and I presume to our minds also, which were created and are sustained by Him. Of that no doubt can exist, because elsewhere he has laid down as clear this ubiquity, called, as you know, *essential* ubiquity, to contra-distinguish it from *potential* or *virtual*. You find this plainly stated in the Principia—here is the celebrated General Scholium: "Omnipresens est non per virtutem solam, sed etiam per substantiam"—"In ipso continentur et moventur universa, sed sine mutuâ passione."* Therefore it is quite manifest that, in here treating of Instinct, that is, of the operations of animals, he considers the Deity's action as different from that general direction which he ascribes to Him over matter and mind by His essential ubiquity. In other cases He acts on matter and mind, and in the case of mind, He acts on matter mediately or through the agency of mind, which mind He moves. But here He acts, according to Sir Isaac Newton, directly on matter, and is the moving and acting principle of animals; and such has generally been the construction put upon his words as you have them here in the 31st Query. It has been so stated by so popular a poet as Pope, and also, though with less precision, by

* "He is omnipresent, not virtually alone, but substantially"—"In him all things are contained and moved, but without mutually affecting each other."—Principia, lib. iii., Sch. Gen.

Addison. The former takes the distinction, in his Essay on Man, between brutes as only having volition, which in them acts for both willing and reasoning: while men have the double faculty. He expresses himself with his wonted felicity:—

> "See then the acting and comparing powers,
> One in *their* nature, which are two in ours;
> And Reason raise o'er Instinct as you can,
> In this 't is God that acts, in that 't is Man."
>
> *Essay, Ep.* iii.

Addison, in his 120th Spectator, after giving many instances in which he jumbles together Instinctive and Intelligent operations, concludes with the remark, that "they can no more be explained than gravitation can; and come not from any law of mechanism, but are an immediate impression from the first mover, and the Divine energy acting in the creature."

A. This dogma of Newton is certainly great authority—the greatest human authority. For it is the opinion—and, regard being had to the awful nature of the subject as well as the contemplative and religious nature of the man, it is probably the well-considered opinion—of the greatest inquirer into nature that ever existed, and whose conjectures have been almost as happy, and are certainly quite as marvellous, as his complete discoveries.

B. Observe, too, that it is the opinion of his maturer years. The Scholium to the Principia was added in the later editions—when written does not clearly appear, but the second edition was published in 1713, and the third as late as 1726. The 31st Query to the Optics was added at a time which can be fixed better. The first edition of the Optics, published in 1704, had not the queries. The second,

published in 1717, had them; and the third edition was corrected by the author's own hand a short time before his death; from which corrected copy the one I am now citing was printed in the year 1730, after his decease. But as he first published this passage in 1717, and was born in 1642, he was then in his 75th year, and had long before made all his discoveries.

A. I quite agree that as far as mere authority goes, no opinion ever had so great a weight—nevertheless we have the same illustrious man's authority, and example too, to teach us that it is by our own reason alone that we ought to be guided in philosophizing, and we must bring to the test of that canon even HIS best considered opinions.

B. This I of course freely admit. Let us, then, examine a little this doctrine of immediate interposition—which regards the work of the bee, for instance, as the direct and immediate operation of Divine wisdom and power.

A. I need hardly warn you against being seduced by another bias, as powerful as Sir Isaac Newton's authority—the disposition we must have, if possible, to believe in a doctrine which, by exhibiting the finger of God as perpetually moving and working before our eyes, seems to bring us constantly into His presence, as if we saw a perpetual miracle wrought, and almost enables us to commune with the Deity, as the Patriarchs did of old. The gratification to us, as men, of reaching this position, should not make us, as philosophers, open our ears the more readily to any unsound or inconsistent reasonings, assume facts on slight grounds, or, passing over flaws in the argument, receive easily erroneous conclusions from what we see.

B. Again I entirely agree with you. Far from making greater haste to reach a position so delightful, I should take the greater care of my steps, that I might not slip and fall by the way: for that the road is slippery, the light glimmering, and the route over high ground, leading through precipitous passes, must, I think, be admitted freely. But let us step on cautiously as we have hitherto done.

A. We left off with the deduction that brutes act from a principle, a *thinking* principle, a mental principle, something different from their bodies and from surrounding objects, but that they act towards an end of which they are ignorant, and accomplish that end without design, though very possibly they may also in so acting accomplish some intermediate end of which they are aware, and which they intend to attain.

B. We may add another thing to the proposition. The end which they accomplish blindly and instinctively is far the more important of the two, admitting that there is another and intermediate one. For, suppose your theory to be correct, that the solitary wasp gratifies some sense in carrying caterpillars and the bee, in making hexagons and rhomboids, it is plain that this is a very trifling matter; it neither feeds, nor clothes, nor lodges her, nor her brood; whereas, the purposes to which those works are subservient are the continuation of the species of the insects respectively—the greatest and most favourite end in nature.

A. True; and you may add another thing, which I allow, even if my theory be ever so certainly correct—that the only possible use of the intermediate end is the accomplishment of the other end—for if

you grant me that the wasp carries caterpillars, and the bee makes geometrical figures, to please themselves, or gratify some sense, it is of no importance that either should receive that gratification: its only use is the unknown and unintended consequence of providing for the unborn issue.

B. We are now then arrived at a very important height, from whence we may survey the subject correctly and advantageously.

A. Let us be quite sure that we have left no obstructions, or rather that we have passed over nothing material—that we have left no objections in our rear, which may rise up and mock any inference we now draw. For instance, are all our facts clear? As to the bee's architecture, some have questioned the theory. I have heard it said that what seems so perfect a structure, and so judicious a dividing out of the space, so as to save room and work and material, is only the necessary consequence of placing a number of cylindrical or globular bodies together; that if you blow many soap-bubbles in a basin they will, by their weight and pressure, settle into hexagons.

B. There never was anything more absurd than what some, calling themselves philosophers, have said without a moment's reflection on this subject. No less a name than Buffon may be cited for such nonsense. There are two decisive answers:—*First,* the soap-bubbles will not make hexagons, although your eye may see straight lines formed by their intersections, but not one hexagon the least like the bee's will you find in all the foam; and *next,* there is not a single globe, or cylinder, or any figure like it ever made by any bee. Huber has seen them, or rather had them carefully observed, when at work;

they first make a groove, and then form its walls into planes, and all the rest is a making of planes and angles one after the other without any circular figures at all. So some one finding the eye of the bee to be a net-work, when greatly magnified, and each mesh a hexagon, thought he had found out why the bee works in that figure. To which the answer was obvious, that men and other animals having circular pupils should, by parity of reason, work in circles. But another answer was just as decisive; that the light entering by a hexagon almost infinitely small no more helps the bee to that figure than if it entered by a circle or a square. Its paws and feelers are to work. Nay, suppose even it had a small pattern hexagon ready made, would its working a large one on that model be at all less wonderful? Not to mention that the hexagon is not the greatest wonder; the rhomboidal bottom of the cell, and the angles which its three plates form with each other, and with the walls, are the wonder, and no one pretends to account for that. I pass over the form of the limbs; nothing can possibly be deduced from them in the smallest degree fitted to aid the bee in her marvellous work.

A. Have not some sceptical inquirers thrown other doubts upon the mathematical part of this great wonder? I think I have heard something of the kind, as if Maclaurin, or whoever was the discoverer, had rather been fanciful, or over-refining, and that the bee had turned out to be not so good a geometrician as they had supposed.

B. Here is a sample of those doubts—though they are not indeed, like Newton's sound conjectures, stated with the modesty of doubts—but

somewhat dogmatically. It was the celebrated Maraldi who first measured the angles, and found them to be 109° 28′ and 70° 32′ respectively. Réaumur afterwards set a young mathematician, pupil of Bernoulli, called Kœnig, to find what were the angles that made the greatest saving of wax, and the result was by his analysis 109° 26 and 70° 34′, being within two minutes of his own measurement, which measurement he had not communicated to Kœnig. But it turns out that the bee was right and the analyst wrong: for by solving the problem in another way I find that he erred by two minutes; and other mathematicians, with whom I have communicated, distinctly find the same thing, and we have also found how the error crept in.*

A. These angles must have been very nicely measured; for the difference of two minutes, or the 2000th part of the lesser angle, is very small indeed. How were the angles first ascertained?

B. Maraldi was a most accurate observer, and he gives the angles, as I have stated, 109° 28′ and 70° 32′; and he gives them to differ with the result of Kœnig's calculus, which was made after Maraldi had measured—so he could not have fancied the amount. But I have reduced it from measuring an angle to the easier operation of measuring a small line. If those are the angles, then it follows that the breadth of the rhomboid is exactly equal

* See this fully explained in the experiments and demonstrations relating to the comb in this volume. There is some contradiction in Maraldi's statement, 'Mém. Acad. des Sciences,' 1712, pp. 310–312; but the above measure has always been considered to be that which he intended to state as his result.

to the side of the hexagon, and you find it appears to be so. Also, if those are the angles, the rhomboidal plates are inclined to one another at the angle of 120°, that of the hexagon; and you find they do not differ when you place them together, one within the other. However, I admit that this is not a very close admeasurement of such small differences; and I presume Maraldi must have employed a micrometer. I have used one to compare the breadth of the plates and sides, and I certainly can find no inequality. At all events, the bee seems entitled to the benefit of Maraldi's previous measurement, which had been thought to put her in the wrong, now that the analyst and not she has been found in error. This, however, is nothing to what follows. A Berlin academician, thinking, I suppose, to do a kindness by Frederic II., objected to the bee, that though, if the dimensions of the cell be given, the saving is as I have stated, yet there is such a great waste of wax arising from those dimensions as proves the saving of wax to be no object. He sets himself the problem of what he calls a *minimum minimorum;* namely, to find the proportion between the length and breadth of the cell which saves most wax; and he finds it something quite wide of the actual proportions. Now, I went over this analysis, and again found the bee right, and the philosopher at fault; for he had wholly left out the hexagonal covering of the cell's mouth, which, whether for brood or honey, there always is; and I found the actual or bee's proportions to save more than the academician's, when this was taken into the calculation. I moreover found the sides to be so much thinner than the bottom. that a shallow and wide

cell would have cost more, even independent of the covering at the mouth. Again, he admits the form chosen to suit the bee's shape, which the form he calls a true minimum never could; but I show that it saves wax as well. Lastly, I have solved another problem of a like kind, namely, to find the angles that save most of the fine or difficult work, which is the angular or corner-working evidently, and that also is the thickest part of the work necessarily. I find the solution gives the very same angles which the bee uses, and which also save wax in the other view. So that she has hit upon the very form which in every respect is the most advantageous, and turns out to be on all grounds right—as indeed we might well suppose when we recollect who is her Teacher.*

A. All this is most satisfactory, and it was worth stopping to state it. However, as we have made a pause before our next advance, it may be just as well to stop for a moment longer in order to consider what the bee's operation really is. How we should go to work had we to build cells is plain enough. Suppose we had discovered, which we should do by mathematical investigation, the proper form, the due proportion of the width to the length, and the proper angles of the bottom or roof—then we should have drawings and plans; and by these we should either cut our planks, if the

* Lord Brougham has given in the original work (*Dissertations on Paley's Natural Theology*, vol. i.) all the mathematical demonstrations by which the positions in the text are shown to be undeniably true. He has also given a variety of curious observations and experiments on the architecture of bees, which appear to have escaped former philosophers. This part of the work, as too abstruse, is unavoidably omitted in the present publication.—ED.

structure were of wood; or if it were of stone, which more resembles the bee's materials, and is, be it observed, much more difficult and complicated to work with, we should, by those plans and by models or frames, run our courses. It would be a nice and difficult work to make this masonry, and would require the builder, both in hewing the stones and in putting them up, to follow the details of the plan in its parts, and without any regard to the general figure or result. He would be wholly unable to succeed if he looked to that; all his building would be awry and out of the required figure; his only chance is to make his plan exact, and his model-frames suit it; and then he has instruments and tools, plumb-lines, squares and plumbs together, in order to raise his perpendiculars. By these he proceeds, for he cannot trust his eye or his hand a moment beyond the mere adjusting his work to his instrument and his plan. Now the bee confessedly has neither plan, except what is in her head; nor any model at all whereby to guide her hand; nor any instrument to adjust her work to the plan in her head; nor any tool to work with except her paw and her feeler, which is as her eye in doing the work. Then how does she work?

B. Certainly, this is a most important consideration. We cannot trust our eye or our hand an instant. We have no exact perception of the line, and no steadiness in pursuing it. We have recourse to plans and instruments because we cannot form our lines by volition, that is, by having a form in our mind and by making our hands follow that form. We therefore must first lay it down sensibly, and then guide our hands by material means. Thus we have no power of forming a dome, an

arch. or a circle, or a perpendicular, or a level, or even a straight line at all, or any one line or form which we conceive in our mind. Far from being able to follow these lines in great works, as roofs and walls and excavations, we cannot even represent such forms on a sheet of paper by our handywork. If we could do this we should work like the insect, who acts immediately, and not through the instrumentality of means. Unable to execute any purpose of our minds, as she does, we have recourse to instruments. We endeavour, as far as we can, to reduce every thing to a physical or material process— to exclude mental operation or agency altogether—to make the whole a material, or as we call it, accurately enough, a mechanical operation. Reason no doubt has taught us to do so; but it has taught us a general rule; and there is little or no reason, little or no operation of the mind, in its application to the particular cases. On the contrary, the use of the rule or method is that it precludes the operation of the mind as much as possible, and makes the whole physical, or nearly so. To take an instance—we reduce, by engraving or printing, the whole operation of drawing a picture, or writing a page, to turning a lever, which does the work for us. So in building, though there is less mechanical facility, we guide our hand by the instruments employed and the lines drawn, making the operation as mechanical, as little mental, as possible. The bee's operation is all mind together. She has no plans, no instruments, no tools. It is as if by waving our hands among plastic materials we formed walls, and domes, and columns, and never deviated a hair's breadth from the perfectly accurate plan. I am very decidedly

of opinion that this essential difference between the works of Reason and Instinct is of the greatest importance to our inquiry: for nothing can more show the peculiarity of the instinctive operation; or more prove that the mind of the agent is as it were the machine, and the instrument, to perform the work, and to perform it with an unerring certainty and with absolute perfection.

A. Does this, which appears to me, as it does to you, a most important consideration, bring us at all back towards the ground of Descartes, which we had passed over as forming a position wholly untenable: I mean, that the insect is a mere machine, fashioned by a perfectly skilful mechanic, and wound up to perform the functions which he designed?

B. Certainly not. The proposition which we have just been deducing from the facts is rather of a kind the very reverse: it affirms that the insect's mind performs the whole operation; it makes the insect's mind the machine, if I may so speak. But let us see to what it also leads or seems to lead us. We perceive there is mind at work, action exerted, effect produced; but we see that the mind is quite unconscious of the effect, and that the action works to a purpose which the mind never contemplated. There is a thing done, an important and rational thing done, but done by an agent who neither intends nor knows anything about it. Here there is design, but there is no designer—an action and an object no doubt; but that action performing, besides what the agent intended, knew, and did, something else (and that something the only important thing), which the agent neither knew nor intended, and cannot possibly be said to have done

at all. This by no means leads us back to Descartes' position, but does it not lead us to Sir Isaac Newton's? The design is manifest; the action is perfectly and surely adapted to it; the purpose is with singular regularity effected; must there not be a designer, and who can that be but the Deity? There is none other that can be suggested even. Must it not be He?

A. Doubtless in one sense it must, as he is the designer of all we see. But how is he more the designer here than he is of the motions of the heavenly bodies, or the growth and germination of plants?

B. As thus. In those cases there is nothing but matter affected, or acting; whatever laws were originally imposed on matter are followed; whatever qualities first communicated to it are displayed: all is material. There was design in the original formation of it, in the prescribing those laws, and impressing those qualities. That design these bodies fulfil; they conform to the primæval and original intention of their being. But there is no renewed design, no repeated intention, no special and particular disposition in each case of action. The Deity made a stone, and made the earth, so that the stone falls to the ground by virtue of the general rule of their formation. He is not to be referred to; he needs not interfere each time the support is withdrawn from the stone, in order to direct the path it shall take. If on that support being withdrawn some interposition were required to decide how it should go—for instance, whether it should stand still or not—although it be admitted, that if it move it can but move in the straight line downwards, the case would more

resemble Instinct, though even here it would be different; for it is as if each hair's breadth of the stone's motion required a new action to carry it on in its course.

A. The Deity created matter so as to obey in each case certain general laws: so he created mind in like manner to obey certain laws in each case. Wherein do the two facts differ, the fact of material and the fact of mental action?

B. As thus. The moving power is wanting in the one case. The law is that matter shall act in a certain way, and mind in a certain way; but is it the mind of the insect that acts when the whole mental process is wanting, namely, the knowledge, thought, and will? Its mind acts, subject not only to a general law, but to a particular impulse each time. Who gives the impulse? Besides, your doctrine of the Deity creating the insect's mind such as to act so in given circumstances, applies quite as much to our Reason as to its Instinct. Let me, however, put a case: suppose we saw a man born blind, to our own knowledge, without any teaching, and without ever having tried it before, move his fingers in the design of giving them exercise, as to keep them warm, &c., but holding a pencil in them, and by the same act producing, unknown to himself, a beautiful and finished portrait, of perfect resemblance to the original: or suppose we saw a man who had been born and lived in a foreign country, and was utterly ignorant of our language, of which he had never heard a word, write a letter in correct English, or a beautiful copy of verses, while only meaning to try whether a pen was well cut, or the ink rightly made—these acts are quite analogous to the Instinct of bees. Nay, we may take a nearer

case, and suppose a man who never had learnt mathematics, and did not know a line from an angle, to solve on a slate a problem of great difficulty with perfect and unerring accuracy, and this while he was only trying the pen and the slate; and suppose he then applied this solution to the combinations of a perfect time-keeper, while he thought he was only cutting off the superfluous pieces of two lumps of brass and steel of which he intended to make weights, he being wholly ignorant of what a time-keeper meant. There is nothing more strange in this than the bee's architecture. It is indeed exactly, and in all its parts, a parallel instance. In all such cases (the extra thing done, and not known or intended, being far more difficult and more important than the thing intended and known to be done), we should at once pronounce that there was a miracle, because of the thing done being without the possibility of the apparent agent doing it unassisted, according to the ordinary laws of nature. In other words, want of power in the immediate agent compels us to believe in the interposition of another agent having the power. There is *dignus vindice nodus*, and we call in the *vindex*. This is the foundation of all belief that there must be supernatural agency where the laws of nature are suspended. But in the cases put there is not only want of power, but of design. If want of power in the apparent agent drives us to suppose or infer the action of another unseen agent, want of intention or design should drive us to infer the intending of another designer, and want of both power and intention should make us infer the thinking of a planner who intends, and the action of an agent able to perform the work: in other words, to infer

the interference of one who has both the will and the power, each of which is wanting in the immediate or apparent agent.

A. In the case you put of a miracle, there is a single instance, and because it is solitary, we say the laws of nature are suspended, and we call in supernatural aid. In the case of Instinct, it is the constant course; it would be a suspension of the law, and a miracle, were it ever otherwise. It is as much part of the law of nature that the animal should do the thing in question without intending it, or knowing how he does it, nay, that he does it at all, as that man should do it knowingly and intentionally, or that the animal should knowingly and intentionally do those other things in which he acts rationally, and not instinctively. Therefore this case does not resemble a miracle.

B. The case of a miracle I did not put in this way or with this view at all. I do not say that the instinctive act of the animal, or of man when he acts merely from Instinct, as he does, though most rarely, are to be compared with miracles as being suspensions of natural law; but only that the same reason which makes us, when arguing from such suspension of natural laws, conclude that some power has interposed different from the powers acting under those laws, requires us, when arguing from the acts done by the animal without either design or power, to conclude that some agent has interposed of power sufficient, and some intending and designing being of will fitted, to do the acts in question. Suppose, to put again my first case with a variation, we saw a blind man draw a likeness as often as he stretched his fingers with a pencil in them, and every foreigner of a certain

class write good English verses as often as he tried a pen, and every man of a particular description make excellent time-keepers as often as he cut away the parings of the metal balls he was forming into weights—we should in every such instance of these general laws (as they could now be) have a right to draw an inference of one and the same kind. What would that be? Manifestly that here the same thing was done without knowledge or intention, which in the other class of cases (those where reason and experience operated) was done by means of knowledge, and with intention. For the gist of the question and the whole difficulty is this—that we have two classes of cases—the same act done in the one class knowingly and intentionally, and in the other, without knowledge or intention—and as in the vast majority of all acts taken together of all kinds of agents, we can see no such thing—indeed, cannot form the idea of such a thing—as an act without power and will to do it, or a thing resulting to all appearance from intention, because in itself such a thing as we should do if we intended a given thing, and yet without any Being to intend, so we are compelled to infer the power, that is, the knowledge of the intender.

A. Indeed, it must be observed, that when we speak of a miracle we mean, and commonly do mean, two things, not only the fact seen of the laws of nature being suspended, but the inference drawn of some power interposing capable of suspending them, and therefore above them, and having sway over them; and this inference arises from the necessity under which we feel of accounting for the phenomenon observed by supposing an adequate

cause; in short, from our being unable to conceive anything done without a cause. The ordinary powers with which we are acquainted fail to account for this event, and we therefore infer another power to be in operation.

B. Certainly it is so; but then this is precisely the case with Instinct, as compared with the other phenomena, namely, those things done with both knowledge and design on the part of the agent, that is, things in doing which the agent is known to us, and intends, and knows what he does. Suppose, according to the case so well put by Paley, in the beginning of his book,—suppose you find on a common a watch going and producing manifestly an effect according to its construction; this would show a design in its maker; but only a former, or bygone, a spent and executed design. Nothing would be seen designing or intending, as it were, before your eyes. Suppose, then, you saw the watch, or other machine, making a second and third machine, but not by mechanical contrivance—for that, too, like the case put by Paley, would still only be evidence of a former, or bygone, or executed design,—you must suppose a new watch to be made before your eyes without any material agency, or, which is the same thing, made by a machine wholly incapable of performing the operation itself. Then you would necessarily infer from these the existence of some being, some thinking and designing and skilful being, capable of doing what you saw, that is, of making the machine; and you would suppose this just as much if you saw an incapable body performing the operation, as if you saw the operation performed without any visible or sensible material agent at all. Now,

this is precisely the case of the bee: it is the incapable body or being.

A. May it not all be said to be on*ly* another inference of original and general design, as we deduce that conclusion from the structure of the limbs of animals, and the functions suited to that structure which those limbs perform?

B. Even if it were so, there is the broad distinction between mere mental and mere physical agency; and the difference between the inferences to which those agencies respectively lead. But I apprehend the difference is greater still than this. The two cases are not at all the same or alike, hardly even analogous. We never know of matter, or any combination of material parts, acting or affected but in one way. We have not matter with, and matter without, gravity, cohesion, impenetrability. But if the phenomana of instinct are to be regarded as only one class of mental phenomena, we have here two kinds of mind, endowed with wholly different qualities, and acting in wholly different ways; one kind such that the being possessed of it neither knows nor intends what he is doing, and yet all the while does exactly as if he both knew and intended. Nay, in one case, the agent possessing this mind is manifestly able to act; in the other, he is as clearly incompetent in any way that we can conceive. If no being is here concerned except the apparent, and unconscious, and impotent agent, it is like matter gravitating to a centre which does not exist: and then, to make the thing still more incomprehensible, and the difference between matter as subject to general laws and this case the more extreme, both these kinds of mind are found in the same individual; for he

sometimes uses, as it were, the one, sometimes the other; he sometimes acts knowingly and intentionally; sometimes blindly, as an instrument to do he knows not what, nor cares—as if we had a piece of matter, a lump of metal, for instance, which at one time was heavy, and at another flew about in the air.

A. There is certainly a material difference; and I should not much wonder if we were, sooner or later, driven by the extraordinary nature of the case to some new conclusion. These things have really not been sifted as they deserved. Men have rested satisfied with general and vague statements, and I suppose their attention has been too much engaged by the great curiosity of the facts connected with the subject to let them closely reason upon the theory. However, I must again recur to my supposition, and refuse to quit this position where we now stand until we have examined it more accurately. There are two kinds of mind, I will say. Then the Deity created two kinds originally. As he created two kinds of substance or existence, mind and matter, and as he endowed these with different qualities, so did he endow the two kinds of mind with different qualities. As he made matter solid and heavy, and made mind imperceptible to the senses, but endowed it with consciousness, so he gave the two kinds of mind different qualities—both of course must have consciousness, which I take to be the essence of all mind, at least we cannot conceive mind to exist without it—but one he made such that it could act rationally, knowing and intending all it did—the other such that it acted without knowing or intending. This hypothesis, you perceive, gets rid of the necessity of supposing

no knowledge, will, intention, at all, mind is not concerned in the operation, and we come to the Cartesian hypothesis, that the animal is a machine. Therefore knowledge and design there must be; and it must either exist in the animal mind or in some other mind which uses or employs the animal as an instrument. Can this higher mind do so beforehand, or otherwise than by constant operation, that is, constant exertion of itself?

A. Then are we not getting either to the Deity being the soul of the animal, or to the mind of the animal having none of the qualities constituting mind?

B. We may suppose the mind to be the mere power of giving voluntary motion to the limbs, and to consist of no other quality, unless it thinks and intends. Then the Deity may have suffered it to have these powers, and to use them in some things, and there His own intelligence does not interfere; but not to use such powers in other things, and there His intelligence does interfere.

A. There *is* knowledge and intention in the animal. The bee, for instance, knows it is carrying wax to a given place, and placing it in a given direction. So far as the thing is done, the agent knows, and wills, and intends what it is doing, and this in every possible case of instinctive action.

B. But the whole question arises, not upon what the bee knows and intends, *e. g.*, putting particles of wax in a place, but upon what she cannot possibly know anything about—the giving her work a peculiar form, most difficult to discover at first, most advantageous for a certain end, and still more difficult to follow and work by even when discovered. The question always is, who designs

and knows these things unknown to the Bee? And we cannot conceive the Deity acting thus originally through a future and non-existing animal; although we can easily enough imagine Him acting through an existing animal at the time. This is supposable on the theory of essential ubiquity, or indeed upon any theory of ubiquity, even virtual. It merely requires ubiquity—whether of essence, or of power—some ubiquity—which no one denies who believes in a Deity at all.

A. A child shall place together different lines and angles, or other parts of figures, so as to form certain diagrams. The figures he thus unwittingly makes have certain properties quite unknown to him. All he intends or knows is to put the parts together; the rest is consequential, arising from the necessary relations of number and figure: so in cases of physical or contingent truth: he may do, and mean to do, and know that he is doing, what will form a certain combination; but the laws of nature acting on that combination, produce, unknown to him, effects which he never intended, and knew nothing of; as if he mixed sulphuric acid and oil of turpentine, and there was an explosion; or an acid and an alkali, and there was a neutral salt and a crystallization.

B. This, when examined, we shall find either to be a case wholly different from the one in question, or to be only *idem per idem*, as lawyers say when they have a case put which is like enough to the one in hand, but just as difficult to resolve; so, in either way, the argument will remain unaffected. If the child plays with the things at random, and they happen to fall into a certain shape once, or it may be twice, that is certainly not the case of the

bee, which regularly, and without ever failing, always makes the figure required; and, upon being obstructed in her operations, varies her means till she can again attain the particular form. If, on the other hand, the child places the things always accurately in the same way, then the case not only resembles the one in question, but becomes identical with it; all the arguments and all the difficulties apply; it is exactly *idem per idem*. So again, if the child does a certain thing with knowledge and design to do that and no more, leaving the rest to be done by some law of matter unknown to it—this is not the case of Instinct; for the bee does all that is done by the operation of mental agency; the wall, the hexagon, the rhomboid, are all made by the bee's living power; she does not place wax and leave it to fall into hexagonal forms, as we mix salts and leave them to crystallize into cubes or hexagonal prisms; she forms the figures herself, and when she has done her work nothing remains to be done further by any law of nature. But if the child makes a combination constantly and correctly, say some useful substance not to be made by accident or random working, then the case becomes the same, and the argument is not affected by it in any way.

A. You often complain of my obstinacy; which I call sometimes caution, and sometimes slowness, according as I may be in a self-complacent or a modest humour.

B. Then, as I do not remember ever to have seen you in the former state of mind, I am sure you must always call it slowness, which no one else ever called it; but I will call it caution, and ask what more it leads to?

A. To this—that I would again hanker after my doctrine of general laws, primarily impressed on matter and mind both. You argue, and argue justly, that the operations of matter and of mind are to be kept apart; you allow that the material operation is explicable by and referable to general laws; you allow, too, that whatever is wrought by the operation of mind, acting as such, is explicable by and referable to general laws of mind, originally imposed, *e. g.*, to desire what is agreeable to it by its general constitution; to reject what is by the same constitution disagreeable. But you say that we see, in the case of instinctive actions, operations for which desires and aversions will not account, and operations carried on as if by the most refined and correct reason, and yet without any material or physical interposition; that is, without any instrumentality whatever, as if a cast were made without a mould, or a print without a plate. From hence you say it is difficult to understand how there should not be here an intelligent being, as well as mere desires connected with the senses—a cause connected with the understanding. Now, hankering as before, I still ask—though perhaps, after our long argumentation, with somewhat diminished confidence—may not this be accounted for by supposing a general law adapting and adjusting all the proportions beforehand? May not the Deity have originally appointed the taste or desire of carrying caterpillars in the solitary wasp, for instance, exactly to the very number required to feed the worm after born, when, by the laws of matter, the egg shall have been hatched and the grub produced? So may not the bee form her hexagons and her rhomboids, in consequence of a

gratification felt by a fore-ordained law of her nature, in following those lines and angles, and no other?

B. That this is barely conceivable I may perhaps admit. But it is wholly unlike any other operation of the senses and desires of which we have any knowledge. It means this, that each desire is so nicely adjusted as to produce in the animal the effects of reason and intention in man, or of reason and intention in the same animal when acting with design and knowledge, and not instinctively. The bird is to have a pleasure in bringing sticks or moss to a certain place, just at a given time, and putting them in one position—the solitary wasp, in bringing, and only in bringing, for it never tastes, a certain number of caterpillars, and to have no gratification in bringing one more, but the strongest desire, because a sensible pleasure, in bringing the eleventh as much as the first—also no kind of gratification in carrying the eleventh to any other place than the same where all the other ten were put—also a like pleasure in forming the hole for them, without the least regard to the use she is to make of it, nay, ignorant beforehand of its being to have any use; and yet all the pleasure of carrying caterpillars is to consist in carrying them to that particular hole, and there is no gratification to be derived from carrying them to a place one hair's breadth on the right or the left. Still more—it means that the bee is to have such a gratification as proves irresistible, and occupies her whole life, in tracing certain lines and angles; and yet this strong desire is so far under control, even of reason, that on obstacles being interposed, other lines and angles are to be made, reason suspending

the desire for the moment. So that the law originally imposed, and the quality impressed on the mind, was not one and inflexible, to do a certain act in all circumstances, viz., to follow the impulse of the desires implanted, and which form the animal's nature; but it was a law or order coupled with a condition, and, as it were, giving a discretionary power provisionally, or a power to be used in certain circumstances; it was as thus—a law or order to do a certain thing, to obey the impulse of the desire, unless certain events shall happen; and then and in that case to cease following the impulse of the desire, and to follow another guide, or rather to use a faculty, namely, reason, and act according as it should direct, allow, or recommend in the circumstances. Now, in the mere union of desires with reason, while the desires act blindly by impulse and the reason with discrimination, there is nothing at all inconsistent or incomprehensible; it is the ordinary case of all mental operations. But the peculiarity of the case now supposed is that the desires act exactly like reason, producing the very same effects unknown to the agent which reason does with his knowledge. Are we not then calling different things by the same name, when we say that it is the influence of desires and appetites which makes the bee form her cell and the spider her web? Might not the same kind of argument be applied to the operations admitted on all hands to be those of reason, for example, the investigations of Newton or Lagrange? Might it not be said that they were influenced by an irresistible propensity, from deriving some gratification in drawing one line and using one divisor rather than another? But we know

this not to be the fact. Why and how? Only from their statements and our own consciousness. But for this, the same argument might be used, and no one could refute it. So in the case of the animal we argue thus, because we cannot ask her and learn how she works. The impulse (it must all along be borne in mind) of which the argument speaks is a physical one, *i. e.*, the effect of some external object, or, which is the same thing, some operation of the animal's body, on her senses; it is a gratification of this specific kind which the explanation assumes—if not, it explains nothing. Then how little resemblance does any such gratification which we can form any idea of (leading the bee to her lines or angles, and the solitary wasp to her carriages and deposits) bear to what we know and feel to be the ordinary nature of physical gratification, and the desires connected with it?

A. This consideration has much weight—I mean the way you put the question as to the mathematicians. It seems to show that we have just the same right, in the case of the animal's instinct, to conclude in favour of design and reason, and an intelligent agent, and to conclude against its being animal impulse or the direct operation of the physical senses, as we should have, did we see the mathematicians at work, observe their process, and mark the result congruous with that process, before we spoke to them on the subject of how their working was conducted. Indeed it is remarkable that we are in point of fact just as much without the evidence which the thus inquiring of them would afford, as we are in the case of the animal; for who ever asked the question of either Newton

or Lagrange, and yet who doubts that both worked their problems from knowledge with intelligence? The reason why we do not ask them is, that we have no kind of doubt in our minds; the view of the operation is enough for us. This is because we say to ourselves, "If I did so and so, I know it would be from knowing and meaning to do so and so, and not from any physical gratification." This inference we transfer to others, by saying, "Therefore I believe they act in like manner."

B. Certainly; and this, observe well, is the foundation of all our reasoning as to design. The only argument we ever have or can have in favour of any intelligent cause, from seeing the adaptation of means to ends, on surveying the works of nature, is, that, if we had done so and so, we should have had the design. All we see is the fact of an adaptation; the inference of a cause, or of a designing being, rests on the kind of reasoning you have just stated. So that in reality we have reached this important position, that our argument for the existence of a designing cause at all in the universe rests on no better, indeed no other foundation than our argument that instinctive action proves an interposition of the Deity at each moment.

A. I must further observe, however, that beside the great weight of this consideration as last presented, I feel the difficulty of the hypothesis of an original law generally imposed to be much aggravated by the consideration you adverted to at the same time, of a provisional and conditional law—a law to operate or not, according to circumstances, as if two implements had been given to the animal, Instinct and Reason; for I feel the very gratuitous

nature of this assumption; and I know that there is not a greater proof of our reasoning being merely hypothetical on any question than when we find ourselves obliged to mould, refit, and modify our hypothesis, in order that we may adapt it to the new observations of fact.

B. But there remains a difficulty still more insuperable in your way, which you do not yet advert to. The supposition of a law, and a provisional or conditional law, is all along founded on the assumption of a person to obey it, to act instinctively, unless a certain thing happens, and then to use Reason till a certain other thing happens, and then to fall back upon Instinct again. What can be more gratuitous, not to say absurd? The supposition that the Instinct is to cease and the Reason to begin in a certain event, implies that the animal acting by Instinct all the while was reasonable and intelligent, else how could he know when to lay down his Instinct and take up his Reason? If I send a man to go straight on till he meets a messenger, or sees a finger-post, he is just as much a rational agent all the while he does not deviate from the way, as he is when, meeting the messenger or seeing the guide-post, he does deviate. So that the theory involves here this absurdity, that the instinctive action is all the while an intelligent and rational operation, contrary to the supposition. I can really imagine nothing more decisive or demonstrative than this—and I purposely kept it to the last.

A. Perhaps the end is not yet come; you have said nothing of the known errors or mistakes of instinct—and thus I reserve also my strongest argument to the last. I own that it was this consi-

deration which, always meeting me, drove me to deny the Newtonian doctrine, and to find any or every other escape from it; for surely if the Deity is always acting, there can be no mistake—every thing must be perfectly successful and quite certain. Yet how many cases of mistaken instinct do we see? Mules begotten; flies deceived by the smell of the stapelia to lay their eggs where they cannot breed the maggots, supposing the vegetable an animal substance putrefying; and many others. Now, if this was only the result of similar desires originally implanted, there is no difficulty; for the law would be to follow that smell, and this law is obeyed.

B. Now, I really think you have just yourself answered your strongest argument; for you admit there was that general law. Had it no design? Doubtless, and but one, to lead the animal towards its food, and the nest for its young—the two great objects of all nature, preserving the individual, and continuing the species. Yet here they fail in particular instances, and do neither. Then is not this a defect or imperfection in the general law, detracting, *pro tanto*, from its adaptation to work its undoubted purpose? The same Being gave the general law whom the Newtonian theory supposes to be the particular agent. Then is it not just as inconsistent with His perfections to believe He has made a faulty statute, as to suppose that He makes a mistake in particular cases? Can there be any difference at all here?

A. How do we get out of this in the general case?

B. You mean, how do we answer sceptical, or rather atheistical arguments, drawn from these

supposed errors or imperfections? Only by saying, that as in the great majority of cases the design is perfect, and the wisdom complete, it is probable that further knowledge would remove all apparent anomalies, and reduce everything to order, and to a consistency with perfect wisdom and skill. In truth, we always assume design, even where we cannot trace it. The physiologist never supposes any part which he sees produced, as the spleen, to have no use; but rests satisfied that there is a purpose, though he has failed to discover it; and he hopes that it will hereafter be revealed to his inquiring eye. So when he finds apparent imperfection, he has a right—nay, it is sound logical reasoning—to suppose, that further knowledge would prove it to be perfect, as in the vast bulk of cases he has found perfection. The instances of erroneous or defective instinct are as mere nothing compared to those of true or perfect instinct.

A. We also approach here the argument on the Origin of Evil. There is something to be said, though perhaps not much, as to the irreverent nature of the supposition that the Deity acts, considering the meanness or impurity of some instinctive operations, and the trifling nature of others.

B. You may well say, not much in this; there is absolutely nothing at all. Our present argument only refers to physical, and not to moral considerations. Moral feelings or actions are of course not instinctive at all. There is no blame where there is no choice—no knowledge—no intention—no reason. Then, as to indifferent acts; there is nothing small, or mean, or impure in the Deity's eye. There is nothing in this more than is sometimes, without due consideration, urged against the doc-

trine of Essential Ubiquity. It all proceeds upon a forgetfulness that the Deity cares as much for one creature as another; all are alike proofs of his wisdom; all alike objects of his favour. So as to matter; there is nothing impure or disgusting, except in relation to our weak and imperfect senses, which are, for wise purposes, so formed as to delight in some things and to repudiate others. This is all relative, and relative to ourselves and our imperfect nature. To the Deity it can have no application. The structure and functions of the maggot, bred in the most filthy corruption that can disgust our senses, exhibits, even to the eye of the philosopher, how cumbered soever with the mortal coil, as marvellous a spectacle of Divine skill and benevolence as the sanguiferous or the nervous system of the human body, or the form of the most lovely and fragrant flower that blows.

A. I think the instinct of hunger has begun to operate upon my structure; whether stimulated by the operation of the gastric juice upon the coats of the stomach, or how otherwise, I do not stop to inquire. Nor do I apprehend that our good hostess's instinctive love of order and method would approve of our keeping dinner waiting.

B. Your own excellent mother was the pattern of that regularity, as of so many other admirable qualities; and the intercourse of society was in this, as in far more important particulars, greatly reformed by her example. Therefore let us adjourn our further discussion, of which not much remains, at least not much that is difficult, till to-morrow.

BOOK OR DIALOGUE III.

ANIMAL INTELLIGENCE.—(FACTS.)

A. It must be confessed, that for a subject so extremely amusing as well as interesting in a higher view, Instinct has been giving us but little matter of entertainment. I question if any persons ever talked upon it for so many hours without almost a single anecdote, or illustration of any kind from the facts, which are inexhaustible in variety, and every hour present new matter of wonder. Indeed, those ordinarily known are full of interest; and we have been going on with, I think, two, the bee and the solitary wasp, never even casting a look over the rest of this boundless and variegated field.

B. Why truly so; and the reason is plain enough. We had a problem to solve, and we set ourselves to try our hand at it. We assumed that the whole facts resembled those few to which we applied our arguments, or from which we drew our inferences; and our choosing two was quite right and safe—indeed, one rather than two, for we have dwelt more on the solitary wasp than even the bee, because no question could ever be made in her case of training or traditionary instruction. I do not at all repent of having pursued this course; it

has prevented digressions and distractions, which would have ensued, had we gone upon the facts at large. We should have been perplexed, sometimes by questions of evidence, sometimes by minute differences of no importance to the argument, sometimes by analogies only calculated to mislead. Our way has been to pitch upon a good example or two, which in some sort embody the subject, as far as matter of fact is concerned—an abstraction of Instinct, as it were, without immaterial particulars—and to confine our reasonings and our illustrations to that. However, there can be no sort of reason why we should not now reward ourselves with a little of the entertainment which, as you say, so amply belongs to this great subject.

A. The Instincts which we have been considering as our choice examples, especially that of the bee. are certainly the most wonderful of all the animal phenomena. But the cases where sagacity is shown, and which seem really quite inconsistent with the doctrine that denies brutes all rational faculties, are most frequently cited to raise men's wonder ; and, as I take it, for this reason, that we set out with supposing the common animals to be wholly devoid of intelligence, and are astonished to find them sometimes acting as if they had it—while th operations of Instinct being in many brutes above what any degree of intellect can account for, we refer these to a totally different origin.

B. I quite agree with you. Perhaps one need not go much more now into examples of Instinct. None can exceed that of the bee, which has from the beginning of the creation been working, and all over the world working, in the same manner, upon

the successful solution of a problem in the higher mathematics, which only the discovery of the differential calculus a century and a half ago could enable any one to solve without great difficulty at all; and which a celebrated mathematician, who was devoted to the ancient geometry, though an adept also in modern analysis, when he solved, conceived that he had gained no small victory for that favourite science by showing that it could solve this question of maxima and minima.

A. Nevertheless, there are other wonders of a like kind, those which show Instinct to be as great in manufactures as the honeycomb proves it to excel in architecture. The paper-making of the wasp is of this class. She makes a paper as excellent as any manufacturer at Maidstone; she has been for sixty centuries acquainted with what was only discovered by men between five and six centuries ago—for I think the question raised by Meerman confined the discovery to the years between 1270 and 1302, though afterwards a specimen was produced as early as 1243. Moreover, when some of the more recent improvements, as the lengthening and equalizing the fibres, are considered, it is found that the wasp was all along acquainted with these useful devices also.

B. I have observed, too, in examining her structures, that she makes two kinds of paper, white and brown, the former being fine cambric paper, and the two glued together by an excellent smooth and durable kind of cement. The white paper, I find, takes the ink as well as if it were sized.

A. When stories are told to excite wonder under the head of Instinct, they generally relate not to

Instinct, but to the Reason or Intelligence which animals show. However, there are other wonders of Instinct beside those we have been adverting to. The uniformity of the operations of animals of the same species everywhere and at all times is remarkable; and the expertness they show from the first clearly proves that instruction and experience has nothing at all to do with the matter. Bring up a crow under a hen or under any other bird, it makes as exact a crow's nest as if it were born and bred in a rookery.

B. So Maraldi found that a bee an hour old flew off to the proper flowers, and returned in a little time with two pellets of farina, then supposed to be the material for making wax, now known to be used only in making bees breed, since the capital discovery of our John Hunter showed wax to be, like honey, a secretion of the animal. Nay, before birth too the animal works to an end, and with the same exact uniformity. The inimitable observations of the great Réaumur show that the chick, in order to break the egg-shell, moves round, chipping with its bill-scale till it has cut off a segment from the shell. It always moves from right to left; and it always cuts off the segment from the big end. There is no such thing as a party of what Gulliver calls "little-endians" in nature. All these singular Instincts, however, regular and uniform though they be, are, when circumstances require it, interfered with by the rational process of adapting the means to the end, and varying those means where the end cannot otherwise be attained. But Instinct is regular and steady in all ordinary circumstances.

A. The vast extent of the works performed by

animals, especially by insects, is no less wonderful than their instinctive skill. This arises from their immense numbers, and the singular Instinct whereby they always work in concert when gregarious. What can be more astonishing than the work of the termites, or white ants, which in a night will undermine and eat out into hollow galleries a solid bed or table, leaving only the outside shell or rind, and soon will make that too disappear!

B. Or the ant-hills in tropical countries, twelve and fifteen feet high, as if men were to make a building the height of the Andes or Himalaya Mountains, when they are vain of having made the little pyramids? But let us go to instances of the other class—of Intelligence.

A. Had we better begin this new discussion by ascertaining whether or not the doctrine of a specific difference between man and the lower animals is well founded; or had we better begin with the facts?

B. I am upon the whole for beginning with the facts; and I should come at once, as we have just been speaking of concerted operations of Instinct, to the case of the beaver, which is, under the head of Intelligence, almost as wonderful as the proceedings of the bee and the ant are under that of Instinct.

A. But before quitting the bee, and the ant, and the wasp, let us just observe their rational acts. They are nearly as notable as their instinctive ones. The bee, upon being interrupted by Huber in her operations, shortened the length of her cells; diminished their diameter; gradually made them pass through a transition from one state to another, as if she was making the instinctive process subser-

vient to the rational; and, in fine, adapted her building to the novel circumstances imposed upon her; making it, in relation to these, what it would have been in relation to the original circumstance if they had continued unaltered. It is found, too, that the ant, beside the wonderful works which she instinctively performs, has the cunning to keep aphides, which she nourishes for the sake of obtaining from them the honey-dew forming her favourite food, as men keep cows for their milk, or bees for their honey.

B. On this discovery of Huber some doubt has lately been thrown; and do not let us trouble ourselves with anything at all apocryphal when the great body of the text is so ample and so pure. But the expeditions of a predatory nature are by all admitted. They resemble some of the worst crimes of the human race; the ants undertake expeditions for the purpose of seizing and carrying off slaves, whom they afterwards hold in subjection to do their work—so that the least significant and the most important of all animals agree together in committing the greatest of crimes—slave-trading.

A. With this material difference, that the ant does not pharisaically pretend to religion and virtue, while we bring upon religion the shame of our crimes by our disgusting hypocrisy. But the wasp, too, shows no little sagacity as well as strength. Dr. Darwin relates an incident, to which he was an eye-witness, of a wasp having caught a fly almost of her own size; she cut off its head and tail, and tried to fly away with the body, but finding that, owing to a breeze then blowing, the fly's wings were an impediment to her own flight, and turned her round in the air, she came to the ground and

cut off the fly's wings one after the other with her mouth. She then flew away with the body unmolested by the wind.*

B. I have myself observed many instances of similar fertility of resource in bees. But perhaps the old anecdote of the Jackdaw is as good as any—who, when he found his beak could not reach the water he wanted to drink, threw into the pitcher pebble after pebble till he raised the surface of the liquid to the level of his beak. Lord Bacon tells it of a Raven filling up the hollows in a tree where water had settled.

A. Or the Crows of whom Darwin speaks in the north of Ireland, who rise in the air with limpets and muscles, to let them fall on the rocks and break them, that they may come at the fish. It is said that animals never use tools, and Franklin has defined man a tool-making animal; but this is as nearly using tools as may be—at least, it shows the same fertility of resources, the using means towards an end.

B. It does a little more. It shows the highest reach of ingenuity, the using the simplest means to gain your end—the very peculiarity for which Franklin's own genius was so remarkable. He could make an experiment with less apparatus, and conduct his experimental inquiry to a discovery with more ordinary materials, than any other philosopher we ever saw. With an old key, a silk thread, some sealing-wax, and a sheet of paper, he discovered the identity of lightning and electricity. Here we are instituting a harmless comparison between the bird and the sage: but the crow's genius is said once to have come in collision with the head

* Zoonomia, Sec. xvi. 16.

of a philosopher in a less agreeable manner, when, mistaking the bald skull of Anaxagoras for a rock, she let fall the oyster from such a height that it killed him.

A. But there certainly must be allowed to be even nearer approaches to tool-making, or, at least, to the use of tools, among animals. There are many insects which use hollow places, and some which use hollow reeds or stalks for their habitations.

B. Indeed they do; and perhaps the most remarkable of all proofs of animal intelligence is to be found in the nymphæ of Water-Moths, which get into straws, and adjust the weight of their case so that it can always float—at least, Mr. Smellie says that when too heavy they add a piece of straw or wood, and when too light a bit of gravel.* If this be true, it is impossible to deny great intelligence to this insect.

A. Why should we doubt it? The crow in rising and letting the muscle fall shows as great knowledge of gravitation as the moth in this case.

B. But an old Monkey at Exeter Change, having lost its teeth, used, when nuts were given him, to take a stone in his paw and break them with it. This was a thing seen forty years ago by all who frequented Exeter Change, and Darwin relates it in his Zoonomia. But I must say that he would have shown himself to be more of a philosopher had he asked the showman how the monkey learned this expedient. It is very possible he may have been taught it, as apes have oftentimes been taught human habits. Buffon, the great adversary of brute intelligence, allows that he had known an Ape who dressed himself in clothes to which he

* Transactions of Royal Society of Edinburgh, vol. i., p. 42.

had become habituated, and slept in a bed, pulling up the sheets and blankets to cover him before going to sleep; and he mentions another which sat at table, drank wine out of a glass, used a knife and fork, and wiped them on a table-napkin. All these things, of course, were the consequence of training, and showed no more sagacity than the feats of dancing-dogs and bears, or of the learned pig—unless it were proved that the ape on being taught these manipulations became sensible of their convenience, and voluntarily, and by preference, practised them—a position which no experiments appear to support. Smellie, however, mentions a Cat which, being confined in a room, in order to get out and meet its mate of the other sex, learnt of itself to open the latch of a door; and I knew a Pony in the stable here, that used both to open the latch of the stable, and raise the lid of the corn-chest—things which must have been learnt by himself, from his own observation, for no one is likely to have taught them to him. Nay, it was only the other day that I observed one of the Horses taken in here to grass, in a field through which the avenue runs, open one of the wickets by pressing down the upright bar of the latch, and open it exactly as you or I do.

A. I have known, as most people living in the country have, similar instances, and especially in dogs.

B. But there is one instance of animals catching their prey in a way still more like the tool-making animal. I do not allude merely to the Spider's web, or to the Pelican's use of his large open pouch in fishing; but to an American bird, of which you find a curious account in the *Philadelphia Trans-*

*actions.** It is called the *neun-tödter* by the Germans, as we should say the *nine-killer*, and is found to catch grasshoppers and spear them when dead upon twigs where the small birds come on which it feeds; for the grasshoppers themselves it never touches. These are left, generally about nine in number (from whence its name), the whole winter. and they attract the birds of which the animal in question makes its prey. This is really using one creature as a bait, in order thereby to decoy and catch another.

A. It is certainly a singular and curious instance, whether of Instinct or Intelligence. Are there not stories told of apes using a cat or some other animal—I should suppose rather anything than a cat—to get chesnuts out of the fire?—or what else is the origin of the phrase *cat's paw?*

B. Fable, I presume. Many fables have a real origin in fact: this, I suspect, has not. Monkeys, on the contrary, have been used by men to obtain fruit or cocoa-nuts, by pelting them, and their defending themselves with a fire of nuts.

A. That, however, is a plain instance of sagacity and imitation. They used missiles, as missiles were used against them. Some of our own belligerent measures of retaliation have not always been nearly so judiciously contrived.

B. No: we once, by way of retaliating on Napoleon, helped him; as if the monkeys had pelted themselves, instead of throwing at us. However, an unexceptionable authority, Captain Cook, or at least Captain King, in Cook's last voyage, has a singular instance of sagacity in the use of means, and almost weapons, in Bears. Here you have his

* Vol. iv.

account of their mode of hunting: "The wild deer (*barein*) are far too swift for those lumbering sportsmen; so the bear perceives them at a distance by the scent; and, as they herd in low grounds, when he approaches them, he gets upon the adjoining eminence, from whence he rolls down pieces of rock; nor does he quit his ambush, and pursue, until he finds that some have been maimed."*

A. Certainly, such a well-attested fact as this is very important, and worth a thousand stories of lions and jackals. But you spoke of coming at once to the Beaver, as the parallel to the Bee.

B. Certainly it is, and may be called, in respect of its works, the Bee of quadrupeds, or if you will, of Intelligent animals, holding among them as high a place as does the Bee among Instinctive creatures. Nevertheless, there may be some doubt raised how far Instinct has a share in his operations. They are of great uniformity: all packs or companies of beavers, and at all times, build the same shaped structure, and resemble one another closely in matters which are arbitrary, and therefore cannot be considered as the result of experience or reflection—cannot be dictated by circumstances. This, however, opens a question of some difficulty, which, according to the plan we are pursuing, may be left to the end of our discussion, after we shall have gone through the facts. In considering the beaver, I think we shall do well to follow Buffon, as we did upon the ape, because he purposely rejected everything marvellous or doubtful in the accounts he had received from travellers, and these must have been numerous, for Canada was then a French colony. Those singular animals assemble

* Cook's Third Voyage, vol. iii., p. 306.

in bodies of from two to four hundred, and choose a convenient station in the lake or the river, having regard to the slope of its banks and their woodiness, but also, no doubt, to the frequency of floods in the water. If it is a lake, or a river that varies little in its level, they build their huts without any further structure, but if the level changes much, they construct a dam or dyke, what we call a breakwater, extending eighty or a hundred feet across, and ten or twelve broad: they thus keep the water nearly of the same height, at least they thus always obtain a sufficient depth of water. They then work in concert on the wood, gnawing the trees and branches to suit their operations. A tree the thickness of a man's body they will soon bring down by gnawing round its base, but on one side merely, and they know so exactly the operation of gravity on it, that they make it fall always across the stream, so as to require no land-carriage. It must be observed, in passing, that if they do this the first time they have built, and without any previous experience of falling bodies, the operation must be taken as purely instinctive. They form their cabins so as to contain from fifteen to twenty-five or thirty animals; each cabin has two doors, one to the land, and one to the water, in order that they may either go ashore, or bathe or swim, and sit in the water, which is part of their pleasure, or rather of their amphibious existence. They have in each cabin also a storehouse for placing the parts of the shoots on which they feed (for that they make provision against winter is quite certain), and room enough for accommodating their young when brought forth. The cabins are built on piles, so as to be out of the water;

they are neatly plastered with cement, the animal's flat and scaly tail being used as a trowel in this operation. They are of sufficient strength to resist not only the stream and floods to which occasionally they may be exposed, but also severe storms of wind. The beavers choose to work with a kind of earth not soluble in water, and which they mix with clay. Such is the account of those very rational and intelligent proceedings which Buffon, sceptical beyond all men of stories respecting animal reason, sifted out of all he had heard, after rejecting everything that bore the appearance of exaggeration or fancy. He adds, that a single beaver which he had, showed, in its solitary and domestic state, no signs of sagacity or resources; but rather appeared to be a stupid animal. According to his strange theory, that animals are degenerating in mind, and losing their faculties as man improves (a notion derived from confounding their loss of dominion, power, and numbers, in a wild state, with their loss of intellect),* he considers the beaver as the "only subsisting monument of the ancient intelligence of brutes."

A. They say doubts have of late been cast upon the former accounts of the beaver. I am told, Hearne, one of the best North American travellers, is cited for this.

B. Here is what that excellent observer says upon the subject: you shall judge if he has in the least altered the case. The beavers select, he says, either in small lakes or in rivers, spots where the water is of such depths as not to freeze to the bottom, preferring, however, running water, because this helps them to convey the timber they

* Vol. iv., p. 73, and v., p. 21.

require. They begin by forming a dyke across with fascines, stones, and mud, but without piles buried in the ground; this dyke, whose only use is to give them a convenient level of water, is convex on the upper side fronting the stream; and it becomes solid and strong by repeated repairs, so that the branches sprout, and birds build in the hedge which it forms. Each hut contains commonly one or two, but sometimes four families; and sometimes each is separated from the others by a partition. The hut has a door opening on the water, and no connexion with the land. He then goes on to show how they cut down and build, wherein he differs from the common accounts only in saying that no piles are used in the construction. They work, he says, only by night, and each season they cover the buildings with a new coat of mud-plaster, as soon as the frost sets in. In summer they make excursions in the woods, choosing the trees they mean to make use of, and marking the position of new settlements, when their increase of numbers requires them to plant colonies. Their wood-cutting begins at the end of summer, and the building is carried on in autumn. They have also subterraneous retreats along the banks of the river or lake, to serve as a place of refuge when they may be attacked by the glutton. You perceive, then, that there is very little discrepancy between this account and Buffon's; indeed, there is one remarkable addition to the latter, if it can be relied upon, the precaution taken in summer to choose and to mark out the convenient stations where the new settlements are afterwards to be made.

A. There seems reason to suppose that other animals still preserve their sagacity and act in con-

cert. No one can have observed a flock of pigeons without perceiving that they have sentinels posted to give the alarm. Indeed, wilder birds act in like manner. Fieldfares, when they are occupying a tree which you approach, remain steady and fearless until one at the extremity rises on her wings and gives a loud and very peculiar note of alarm, when they all get up and fly, except one who continues till you get near, as if she remained to see that there really was occasion for the movement, and to call them back if the alarm proved a false one. She too at length flies off repeating the alarm-note.

B. In the forests of Tartary and of South America, where the Wild Horse is gregarious, there are herds of five hundred or six hundred, which, being ill prepared for fighting, or indeed for any resistance, and knowing that their safety is in flight, when they sleep, appoint one in rotation who acts as sentinel, while the rest are asleep. If a man approaches, the sentinel walks towards him as if to reconnoitre or see whether he may be deterred from coming near—if the man continues, he neighs aloud and in a peculiar tone, which rouses the herd and all gallop away, the sentinel bringing up the rear. Nothing can be more judicious or rational than this arrangement, simple as it is. So a horse, belonging to a smuggler at Dover, used to be laden with run spirits and sent on the road unattended to reach the rendezvous. When he descried a soldier he would jump off the highway and hide himself in a ditch, and when discovered would fight for his load. The cunning of Foxes is proverbial; but I know not if it was ever more remarkably displayed than in the Duke of Beaufort's country; where Reynard, being

hard pressed, disappeared suddenly, and was, after strict search, found immersed in a water-pool up to the very snout, by which he held a willow-bough hanging over the pond. The cunning of a Dog, which Serjeant Wilde tells me of, as known to him, is at least equal. He used to be tied up as a precaution against hunting sheep. At night he slipped his head out of the collar, and returning before dawn, put on the collar again, in order to conceal his nocturnal excursion. Nobody has more familiarity with various animals (beside his great knowledge of his own species) than my excellent, learned, and ingenious friend, the Serjeant; and he possesses many curious ones himself. His anecdote of a drover's dog is striking, as he gave it me, when we happened, near this place, to meet a drove. The man had brought seventeen out of twenty oxen from a field, leaving the remaining three there mixed with another herd. He then said to the dog "Go, fetch them;" and he went and singled out those very three. The Serjeant's brother, however, a highly respectable man, lately Sheriff of London, has a dog that distinguishes Saturday night, from the practice of tying him up for the Sunday, which he dislikes. He will escape on Saturday night and return on Monday morning. The Serjeant himself had a gander which was at a distance from the goose, and hearing her make an extraordinary noise, ran back and put his head into the cage—then brought back all the goslings one by one and put them into it with the mother, whose separation from her brood had occasioned her clamour. He then returned to the place whence her cries had called him. I must however add, that I often have conversed with Scotch shepherds coming up from the

cert. No one can have observed a flock of pigeons without perceiving that they have sentinels posted to give the alarm. Indeed, wilder birds act in like manner. Fieldfares, when they are occupying a tree which you approach, remain steady and fearless until one at the extremity rises on her wings and gives a loud and very peculiar note of alarm, when they all get up and fly, except one who continues till you get near, as if she remained to see that there really was occasion for the movement, and to call them back if the alarm proved a false one. She too at length flies off repeating the alarm-note.

B. In the forests of Tartary and of South America, where the Wild Horse is gregarious, there are herds of five hundred or six hundred, which, being ill prepared for fighting, or indeed for any resistance, and knowing that their safety is in flight, when they sleep, appoint one in rotation who acts as sentinel, while the rest are asleep. If a man approaches, the sentinel walks towards him as if to reconnoitre or see whether he may be deterred from coming near—if the man continues, he neighs aloud and in a peculiar tone, which rouses the herd and all gallop away, the sentinel bringing up the rear. Nothing can be more judicious or rational than this arrangement, simple as it is. So a horse, belonging to a smuggler at Dover, used to be laden with run spirits and sent on the road unattended to reach the rendezvous. When he descried a soldier he would jump off the highway and hide himself in a ditch, and when discovered would fight for his load. The cunning of Foxes is proverbial; but I know not if it was ever more remarkably displayed than in the Duke of Beaufort's country; where Reynard, being

hard pressed, disappeared suddenly, and was, after strict search, found immersed in a water-pool up to the very snout, by which he held a willow-bough hanging over the pond. The cunning of a Dog, which Serjeant Wilde tells me of, as known to him, is at least equal. He used to be tied up as a precaution against hunting sheep. At night he slipped his head out of the collar, and returning before dawn, put on the collar again, in order to conceal his nocturnal excursion. Nobody has more familiarity with various animals (beside his great knowledge of his own species) than my excellent, learned, and ingenious friend, the Serjeant; and he possesses many curious ones himself. His anecdote of a drover's dog is striking, as he gave it me, when we happened, near this place, to meet a drove. The man had brought seventeen out of twenty oxen from a field, leaving the remaining three there mixed with another herd. He then said to the dog "Go, fetch them;" and he went and singled out those very three. The Serjeant's brother, however, a highly respectable man, lately Sheriff of London, has a dog that distinguishes Saturday night, from the practice of tying him up for the Sunday, which he dislikes. He will escape on Saturday night and return on Monday morning. The Serjeant himself had a gander which was at a distance from the goose, and hearing her make an extraordinary noise, ran back and put his head into the cage—then brought back all the goslings one by one and put them into it with the mother, whose separation from her brood had occasioned her clamour. He then returned to the place whence her cries had called him. I must however add, that I often have conversed with Scotch shepherds coming up from the

Border country to our great fairs, and have found them deny many of the stories of the miraculous feats of sheep-dogs. Alfred Montgomery and I, the other day, cross-questioned a Roxburghshire shepherd with this result.

A. Many of the feats which we are now ascribing to intellectual faculties may be instinctive operations. How shall we distinguish?

B. The rule seems simple. Where the act is done in ordinary and natural circumstances, it may be called instinctive or not, according as it is what our reason could, in the like circumstances, enable us to perform or not, and according as the animal is in a situation which enables him to act knowingly or not. Thus a bee's cell is made by a creature untaught; a solitary wasp provides food for an offspring it never can see, and knows nothing of. We set these things down to Instinct. If horses, fearing danger, appoint a sentinel, it may be Instinct certainly, but there is here nothing to exclude Intelligence, for they do a thing which they may well do by design, and so differ from the bee; they are aware of the object in view, and mean to attain it, and so differ from the wasp. But these remarks apply to acts done in ordinary circumstances, and which I admit may or may not be instinctive. Another class is clearly rather to be called rational. I mean where the means are varied, adapted, and adjusted to a varying object, or where the animal acts in artificial circumstances in any way. For example, the horse opening a stable-door, the cat a room-door, the daw filling a pitcher with stones. So there is a singular story told by Dupont de Nemours in Autun's *Animaux Célèbres*, and which he says he witnessed himself. A Swallow had

slipped its foot into the noose of a cord attached to a spout in the Collége des Quatre Nations at Paris, and by endeavouring to escape had drawn the knot tight. Its strength being exhausted in vain attempts to fly, it uttered piteous cries, which assembled a vast flock of other swallows from the large basin between the Tuilleries and Pont Neuf. They seemed to crowd and consult together for a little while, and then one of them darted at the string and struck at it with his beak as he flew past; and others following in quick succession did the same, striking at the same part, till after continuing this combined operation for half an hour, they succeeded in severing the cord and freeing their companion. They all continued flocking and hovering till night; only, instead of the tumult and agitation in which they had been at their first assembling, they were chattering as if without any anxiety at all, but conscious of having succeeded.

A. The means taken to escape from danger, and to provide for security, are certainly often of this description, the danger being often of a kind purely accidental and solitary, and the operation of the animal varying in different and new circumstances. Some birds wholly change their mode of building to avoid snakes, hanging their nests to the end of branches, and making the exit in the bottom, in places where those reptiles abound.

B. So too the Ants in Siam make no nests on the ground, as with us, but on trees, that country being much subject to inundations. But you find this change of habits in animals, upon circumstances changing, pretty general. The Dogs which the Spaniards left in the island of Juan Fernandez were found to have lost the habit of barking, when

Juan and D'Ulloa visited that famous spot in the course of their journey in South America. Possibly they found that barking warned their prey, and enabled it to escape. But Dogs in Guinea howl and do not bark, and when European dogs are taken there they lose their bark in three or four generations. This fact, then, is somewhat equivocal.

A. The docility of some animals may, however, as it seems to me, be strictly ranged within the class of facts we are speaking of. Although children, as well as animals, learn through fear and kindness, both operating (and fear alone would suffice), yet it is an act of Intelligence to follow the dictates of both feelings: it implies this process of reasoning,—" If I do so and so, I shall have such a punishment or such a reward." Now the degree to which animals are teachable is wonderful. All Singing-Birds probably learn their whole notes.

B. Yes; Daines Barrington has demonstrated this by numerous experiments* on various birds; the young untaught birds, being placed in the nests of different species of birds, always had the song of those it nestled with; and we all know how a Piping Bullfinch can be taught almost any tune. They seem to have no notion of harmony or melody. I recollect a Green Linnet, which I had when a boy, or rather a mongrel between that and a goldfinch, being placed in a kitchen, and leaving its own fine and sweet notes, to take to an imitation, and a very good and exceedingly discordant one, of a jack which, being ill-constructed, generally squeaked as if it wanted oiling.

* Phil. Trans., 1776.

A. Dogs show the greatest talents in learning. The feats of pointers, but still more of shepherds' dogs, after making all the deductions you have mentioned, are astonishing. It almost seems as if the shepherd could communicate, by sign or by speech, his meaning, when he desires to have a particular thing done. But assuredly the dog takes his precautions exactly as he ought, to prevent the sheep from scattering, and to bring back runaways. Indeed, Greyhounds and other dogs of chace, as well as Pointers backing one another, show the adaptation of, and variation in, the means used towards an end.

B. Retrievers exceed all other dogs in this respect. There was one died here a year or two ago that could be left to watch game, till the keeper went to a given place, and she would then join him after he had ranged the field; nay, could be sent to a spot where game had been left, and where she had not been before. Indeed, she did many other things which I have hardly courage to relate.

A. How were her pups? I have always found such extraordinary faculties hereditary.

B. My worthy, intelligent, and lamented friend, T. A. Knight (so long President of the Horticultural Society), has proved very clearly that the faculties of animals are hereditary to such a point as this. He shows that even their acquired faculties—the expertness they gain by teaching—descends in the race. His paper is exceedingly curious. But I think we need hardly go so far as to his minute details for proof of the fact. It is found that where man has not been, no animals are wild and run away from his approach. When Bougainville went to the Falkland Islands (or, as

the French call them, the Malouines), he found himself and his men immediately surrounded by all kinds of beasts and birds, the latter settling on their shoulders. No navigators had ever been there before. Lord Monboddo says that the same thing had been related to him by navigators.* It seems clear, then, that the running away from man, which seems natural to all wild animals in or bordering upon inhabited countries, is an acquired propensity, transmitted to the descendants of those whose experience first taught it them as necessary for their safety.

A. Have you Knight's paper here? I know the accuracy of his observation to equal his great ingenuity.

B. To that I too can bear my testimony. Here is his principal paper, read lately before the Royal Society. It is given as the result of his observations and experiments, made for a period of sixty years; it is therefore most justly entitled to great respect. He chiefly dwells on the case of Springing Spaniels, and among other instances gives this, which is indeed very remarkable. He found the young and untaught ones as skilful as the old ones, not only in finding and raising the woodcocks, but in knowing the exact degree of frost which will drive those birds to springs and rills of unfrozen water. He gives the instance, too, of a young retriever, bred from a clever and thoroughly-taught parent, which, being taken out at ten months old, with hardly any instruction at all, behaved as well and knowingly as the best-taught spaniel, in rushing into the water for game that was shot, when pointed out to it, however small, bringing it, and

* Origin of Language, b. ii., ch. 2.

depositing it, and then going again, and when none remained, seeking the sportsman and keeping by him. He imported some Norwegian ponies, mares, and had a breed from them. It was found that the produce "had no mouth," as the trainers say; and it was impossible to give it them; but they were otherwise perfectly docile. Now in Norway, draught horses, as I know, having travelled there and driven them, are all trained to go by the voice, and have no mouth.—Again, he observed that they could not be kept between hedges, but walked deliberately through them—there being, he supposes, none in the country from which their dams came.

A. Does he speak of any other animal?

B. Yes, he mentions his observation on Woodcocks, which he could remember having been far less wild half a century ago; for on its first arrival in autumn, it was tame, and chuckled about if disturbed, making but a very short flight, whereas now, and for many years past, it is very wild, running in silence and flying far. He gives an instance of sagacity in a Dog, unconnected with hereditary intelligence. He one day had gone out with his gun and a servant, but no dog. Seeing a cock, he sent the servant, who brought this spaniel. A month afterwards he again sent for the same dog from the same place. The servant was bringing him, when at twenty yards from the house the spaniel left him, and ran away to the spot, though it was above a mile distant. This he often repeated, and always with the same result; as if the animal knew what he was wanted for. Leonard Edmunds tells me of a dog (a Newfoundland spaniel) of Mr. Morritt's, at Rokeby, which has been known to take the shorter road to where he

knew he was wanted, and leave the servant or keeper to go round about. You yourself told me of a dog that met you sporting by a short cut unknown to you.

A. The manner in which animals can find their way is very extraordinary. But though, in many cases, it may be through close observation, and observation the clearer and better remembered because, like the Indian woodsmen, they have so few ideas; yet, in other cases, it seems an Instinct very difficult to conceive in its workings. In truth, if the stories told be true, I question if any instance we have yet examined of Instinct be so truly unaccountable on any principles of intelligence. I have known of dogs sent to a distance, and coming home immediately, though taken in the dark.

B. That might be from smell or track, but stories are also told of dogs and cats taken in hampers, and finding their way back speedily. L. Edmunds had one that was carried from Ambleside to three miles on the other side of Burton, a distance of twenty-seven miles, in a close hamper, by a coach; and it found its way back next morning. Dr. Beattie's account of a dog which was carried in a basket thirty miles' distance, through a country he never had seen, and returned home in a week, is less singular than this, even if it were as well authenticated. Dr. Hancock, in his excellent work on Instinct, which, however, contains fully as much upon the peculiar tenets of the Society of Friends as upon our subject, relates the story of a dog being conveyed from Scotland to London by sea, and finding his way back; of a Sheep returning from Yorkshire to Annandale, a distance of at least eighty miles; and of another Sheep returning

from Perthshire to the neighbourhood of Edinburgh. Kirby and Spence, too, in their *Introduction to Entomology*, state, on the authority of a captain in the Navy, a strange anecdote of an Ass taken from Gibraltar to Cape de Gat on board of ship, and finding its way immediately back through Spain to the garrison, a distance of two hundred miles of very difficult country. The ass had swam on shore when the ship was stranded. This fact seems to be well authenticated, for all the names are given, and the dates.

A. There is no end of such facts, and many of them seem sufficiently vouched. The *Letters on Instinct* mention a cat which had been taken to the West Indies, and on the ship returning to the Port of London she found her way through the city to Brompton, whence she had been brought.

B. That is a work I have often wished to see, and never been able to get. Dr. Hancock quotes it for one of the most remarkable proofs of sagacity and resource in the Goat, and this operation has been, it seems, observed more than once. When two Goats meet on a ledge bordering upon a precipice, and find there is no room either to pass each other, or to return, after a pause, as if for reflection, one crouches down and the other walks gently over his back, when each continues his perilous journey along the narrow path.

A. In Rees's Cyclopædia a story is given as well vouched, of a cat that had been brought up in amity with a bird, and being one day observed to seize suddenly hold of the latter, which happened to be perched out of its cage, on examining, it was found that a stray cat had got into the room, and that this alarming step was a manœuvre to

save the bird till the intruder should depart. But what do you make of carrier-pigeons? The facts are perhaps not well ascertained; there being a good deal of mystery and other quackery about the training of them.

B. I desired one of the trainers (they are Spitalfields weavers generally) to come, that I might examine him about his art, but he has never been with me. I have read and considered a report made to me on the subject. It is said the bird begins his flight by making circles, which increase more and more in diameter as he rises; and that he thus pilots himself towards his ground. But still this indicates an extraordinary power of observation; for they come from Brussels to London and return. Nay, they have been known to fly from the Rhine to Paris. Serjeant Wilde took pigeons of the Rock kind to Hounslow, and they flew back to Guildford-street in an hour. They were taken in a bag, and could see or smell nothing by the way. On being let loose, they made two or three wide circles, and then flew straight to their dovecot. The Serjeant also knew of a cat which a shopkeeper's apprentice in Fore-street had been desired to hang, and found he could not. He then took it in a bag to Blackfriars Bridge and threw it into the river—the cat was at home in Fore-street as soon as the apprentice. He might have made a circuit, but certainly the cat returned in an hour or two. The grocer's name was Gardner—the distance is certainly above a mile, and through the most crowded part of London. The case of bees is referable to Instinct clearly. Honey-finders in America trace their nests by catching two bees, carrying them to a distance, and letting them fly.

Each takes the straight line towards the nest or hive, and by noting these two lines, and finding where they intersect each other, the hive is found. Now the bee is known to have a very confined sphere of vision, from the extremely convex form of her eye. She is supposed only to see a yard or so before her.

A. I fancy we must pass over the subject of migration for a like reason. It seems still involved in much obscurity and doubt, though I take for granted that no one now yields to Daines Barrington's theory, which denies it altogether.

B. Clearly no one; the facts are quite indisputable as far as negativing that goes; and indeed his reasonings are so full of prejudice, or preconceived opinion, and his suppositions for disposing of the facts so strained, that his argument never could have had much weight. One fact seems also not to be disputed, and is referable to Instinct alone. I mean the agitation which, without any cause, comes on upon a bird of any of the migratory classes at the appointed season of migration. It is, in all probability, connected with the sexual impulses.

A. The communication with each other, which animals have by sounds or signs, can, I think, hardly be doubted.

B. The observations of Huber clearly show that ants have a kind of language by means of their feelers or antennæ; and every day's experience seems to show this in other animals.

A. Some believe that they have a notion of what men are saying, and no doubt very strange and lucky guesses have sometimes been made, one of which I wrote you an account of. I had it from a

most accurate and literal person, and it tends to prove that his shooting dogs had found out his intention of going into Nottinghamshire the day after. However, it is perfectly clear that these things are referable to minute and exact observation of things which escape us in the greater multitude of our ideas and concerns. All this, however, only illustrates the more how well animals can profit by experience, and draw correct inferences from things observed by them.

B. Among other instances referable plainly to intelligence must be ranked the devices which one animal is known to fall upon for benefiting by another's operations. The ant enslaving workers is the most curious instance certainly. But the cuckoo laying in other birds' nests, and leaving her progeny to be brought up by them, is another. Nor can this be set down wholly to the score of Instinct ; for there are abundant proofs of her also building when she cannot find a nest, and then she lays in her own, and hatches and rears her brood. This curious and important fact, long disbelieved by vulgar prejudice, was known to that great observer Aristotle, who says she sometimes builds among rocks, and on heights.* Darwin confirms this by the observations of two intelligent friends whom he cites.† The man-of-war bird is a still more singular instance of contrivance, for though its food is fish, it has not such a form as to be fit for catching any, and therefore it lives piratically on the prey made by other fishing birds; hence the name we have given it.

A. Only think of our never having all this while said a word, or more than a word, of either the

* Lib. vi., c. 1. † Zoonomia, vol. xvi., p. 13.

Fox or the Elephant, proverbially the two wisest of animals. Of the former's cunning every day shows instances; but that the elephant should be left to take care of a child unable to walk, and should let it crawl as far as his own chain, and then gently lift it with his trunk and replace it in safety, seems really an extraordinary effect of both intelligence and care, and shows that fine animal's gentle nature, of which so many anecdotes are told by travellers in the East.

B. The amiable qualities of brutes are not quite within the scope of our discussion, unless indeed in so far as whatever things are lovely may also be said to betoken wisdom, or at least reflection. The natural love of their offspring I should hardly cite in proof of this, because it seems rather an instinctive feeling. But the attachments formed between animals of different classes, a cat and a horse, a dog and a man, and often between two elderly birds, may be cited as interesting. One of these friends has been known to be unable to survive the other. I have heard this of two old parrots, upon the best authority.

A. We have said nothing of fishes, or of any marine animals.

B. Why, of these our knowledge is necessarily very limited. That they have remarkable Instincts, some of them resembling those of land animals, is certain. The Sepia, or cuttle-fish, ejecting a black or dark-brown fluid to facilitate his escape, resembles the stratagem of some beasts emitting an intolerable effluvia in the face of their pursuers. The Whale, when attacked by the Sword-fish, diving to such a depth that his enemy cannot sustain the pressure of the water, is another well-

known example of defensive action. I used to observe with interest the wary cunning of the old Carp in the ponds here: there was no decoying them with bait, which the younger and less experienced fish took at once. So little have men formerly undervalued the faculties of fishes, that Plutarch wrote an ingenious treatise in the form of a dialogue, on the question whether land or water animals have the most understanding.

A. How does he treat this odd question?

B. Here is his book; and certainly as far as the first portion of the subject goes, where the merits of land animals are concerned, he sails before the wind. To his first remark I willingly subscribe, that those hold the most stupid doctrine upon the subject (*οἱ αβελτερως λεγοντες*) who say that animals do not really fear, rejoice, remember, rage, &c., but only do something like fearing, rejoicing, &c. (*ὡσανεῖ φοβεισθαι*, &c.); and he asks what such reasoners would think were it also contended that animals do not see, but make as if they saw; nor hear, but make as if they heard; nor roar, but make as if they roared; and, finally, do not live, but only did something like living. He then relates a great variety of facts respecting the sagacity of animals, some of them evidently fabulous (as the love of a dragon for a young woman), and some, as the account of the ant laying in grain, now proved to be erroneous; but he gives others worthy of attending to. Thus, the contrivance of African crows, who, when the water was scarce, threw pebbles into deep cracks of the earth, so as to bring the fluid up towards the surface, and within their reach—the similar cunning of a dog on board of a vessel—the like device fallen upon by elephants

to rescue one that had fallen into a pit—the astuteness of the fox, used by the Thracians as a kind of guide in crossing a river frozen over, to find out whether the ice is thick enough, which the animal does by stopping and listening to hear if the water is running near the surface—the judicious mode of flight in which cranes and other birds of passage marshal themselves, forming a wedge-like body, with the strongest birds at the front angle or point. But when he comes to the other side of the question, and is to state the case for the fishes, we find a great falling off both in his facts and in his evidence. Beside telling very absurd stories about crocodiles in Egypt obeying the call of the priests and submitting to their influence, he dwells upon the Sepia, whose escape in a black cloud of his own making he compares to the tactics of Homer's gods; upon the cunning shown by fishes in gnawing lines to escape with the hook; nay, upon a story he tells of their helping one another to escape when caught, which is plainly groundless; upon the Torpedo, or electrical eel, giving shocks, which is clearly a mere physical quality, and no more indicates reason than the shark using his teeth; upon shoals of fishes, like flocks of birds, forming themselves into wedges when they move from one sea to another, which is certainly true; upon the dolphin loving music, which is purely fabulous, as well as the feats of wisdom and philanthropy that he ascribes to this fish (*μονος γαρ ἀνϑρωπον ασπαζεται καϑο ἀνϑρωπος εστι*); finally, upon all the fables to be found in the poets respecting this fish. After reciting one of these,[1] by way of proving his case in favour of marine animals, he innocently enough says that although he had promised to

relate no fables, he now finds himself, he knows not how, in the company of Cæranus and Ulysses, and so he brings his notable argument to a close.

A. How does he ultimately decide the question propounded?

B. With a verse of Sophocles, intimating that both sides have gained some advantage towards a common purpose; but the victory is given to neither, the umpire pronouncing that both the arguments combined overthrow the doctrine of those who deny Reason and Intelligence to animals generally.

A. There are no modern books which fully discuss this subject systematically, either as regards Instinct or Intelligence. One is exceedingly disappointed in consulting our best writers, whether metaphysicians or naturalists, with this view; and the omission is the less to be excused because there are great opportunities of observing and comparing: this branch of knowledge is eminently suited to inductive reasoning; we live as it were among the facts, and have not only constant facilities for making our experiments, but are in some sort under a constant necessity of doing so.

B. Truly it is as you say. I have often felt this disappointment and this disapprobation. The works of metaphysical writers contain a few scattered suggestions, or dogmas, and with these they leave the subject. Naturalists, who could throw so much light upon it, confine themselves chiefly to the structure and functions of the organs, and leave the mental part of the subject out of view. Yet a physiologist, who also applied himself to this latter branch of the inquiry, would be the person best qualified to grapple with its difficulties and to

throw light upon it. Therefore I learnt with extreme satisfaction that an able and learned professor of Natural History had given a course of lectures upon it at Paris, and was still more gratified to find that he soon afterwards published them. I speak of M. Virey's work; those two thick volumes lying there contain above a thousand pages on the Habits and Instinct of Animals; and to raise my expectation still higher, it professes by its title to deal in facts—for it is called *Histoire des Mœurs et de l'Instinct des Animaux.*

A. Well; I suppose you rushed upon it to slake your thirst?

B. As a traveller upon a delicious and copious spring, and found it a picture; or upon a luscious-looking large peach, and found my mouth filled with chalk. I have had these volumes here these two years, and I can barely now say I have been able to get through them. They are throughout not only written in the very worst style of French sentimental declamation, but they avoid all precision, all details, all facts, as something grovelling, common-place, and unimportant. The constant object is not to find out or illustrate some truth, to describe or arrange some phenomenon, but to say something pretty, far-fetched, and figurative. And all this with an arrangement of the classes of animals so methodical, that on looking at the contents, and finding they proceed regularly from the structure of the globe and the general qualities of its different products, to mammalia, then to birds, reptiles, fishes, and so downwards through the invertebrated animals, ending with zoophytes and mollusca, you naturally expect under each head to have what the title promises, a History of the

Habits and Instincts; and find nothing of the kind from beginning to end, but only trope after trope, one piece of finery after another, nothing but vague declamation long drawn out, an endless succession of the most frivolous sentimentality. Truly such a work, from so learned a naturalist, one who could so well have instructed and entertained us, had he but chosen to be plain and didactic, instead of being brilliant and rhetorical, where all eloquence and ornament are absolutely misplaced, is no small offence in the literary world.

A. I'll assure you our French neighbours are not the only sinners in this particular. I have been somewhat mortified of late years at perceiving a tendency to fine writing and declamation among our own men of science, and I ascribe it, in some degree, to the more general diffusion of scientific knowledge, which naturally introduces the more popular style of composition. Our Society of Useful Knowledge has no sins of this sort on its conscience, because we correct with unsparing severity all we publish; but you may perceive the tendency of popular explication to run in this bad direction, from the kind of matter that is often submitted to us for revision. I am sure I sometimes draw my pen through half a page of fine writing at a time.

B. I will engage for it you do inexorably whenever you find such outrages. My experience is precisely the same; and I am just as severe on those parts, evidently the prime favourites of the learned and very able writers. But we originally set out with firmly resolving to be most rigorous in matters of taste, being aware, as you say, of the tendencies of popular writers. In truth, however, that vile florid style darkens instead of illustrating;

and while we never can write too clearly to the people, we never can write too simply, if our design be to write plainly and intelligibly. But though our Society is free from having any of this blame, I cannot quite acquit of all blame the meetings, however useful and praiseworthy in other respects, of an association which brings crowds of hundreds and thousands together, to hear mathematicians and chemists making declamatory speeches. I must say that those assemblages offer some violence to Science, at least they somewhat lower her by showing her cultivators trying a trade they no more can, or even ought to excel in, than poets in solving questions of fluxions. It is since these meetings, otherwise useful and excellent, rose into eloquence, that I have seen a mathematical discussion, by a very able and learned man, in two consecutive pages of which I reckoned up above twenty metaphors—all tending to darken the subject—to say nothing of poetical quotations without any mercy. Formerly declamations were reckoned so little an accomplishment of scientific men, that when Bishop Horsley filled our Royal Society with a factious controversy, the ministerial side, Sir Joseph Banks's party, had to send for assistance—and where think you they went for an orator?

A. I suppose to some Nisi Prius advocate.

B. Guess again.—No!—So humble were their views of oratory that they went to the other side of the hall, as the lawyers say, and got for their champion, Mr. Anguish, who was Accountant-General, a Chancery man, and had perhaps made as few speeches as any one in that Court. But in the work which I have referred to, and even in those scientific meetings, there is at least much that is

highly valuable, much good grain, and the trash may be rejected as chaff—whereas, in this piece of French declamation all is chaff, and hardly a grain can be gleaned out of the light and worthless matter.

A. Can you find nothing by sifting and bolting it? I generally find something even in the worst books.

B. I will not say that these heavy volumes of light matter contain absolutely nothing; but wondrous little assuredly they have to reward the pains of searching. What can be more hateful than a man of science unable to speak of granivorous animals without terming them Pythagoreans and Gymnosophists; calling the crying baboon of South America a wild Demosthenes, the lion a generous prince, the jackal a courtier; describing the nightingale as appealing to Heaven against the robber of her nest, and the crocodiles as the "sad orphans of nature," because hatched in the sand; nay, carrying his ridiculous fancies into actual practice, seriously explaining the mild temper of one animal by the sweetness of its humours, and the ferocity of another by the acrid juices of its system—all a pure fiction in fact, as well as a gross absurdity in theory! Then mark the consistency of a philosopher—a consistency worthy of the veriest mob. He denounces, as the most atrocious of men, the experimenter on a living dog or rabbit, Fontana, or Majendie, I suppose, and afterwards speaks with the utmost composure of dividing a bee in two, in order to examine her honey-bag. Of the bee, indeed, he seems very moderately informed. He speaks of Aristarchus having devoted his life to the study of this insect, instead of Aristomachus; assumes to be true the notion

long exploded of honey being collected from flowers, instead of a secretion in the stomach; will not believe that wax, too, is a secretion, though he refers unconsciously to Huber's experiment of obtaining it from bees feeding upon sugar and water; and, to set off his modern natural history with a little false classical lore, must needs call the cells "their citadel, or the palladium of their republic."

A. Bad enough in all conscience. But now give us the grain or two of wheat in all this bushel of chaff.

B. First, and this makes it more provoking, the anthor writes clearly and admirably when he chooses to leave off declaiming. There is a long note upon vertebrated and invertebrated animals, showing with much clearness and precision that in the former, which have a cerebral and nervous system, Intelligence prevails; in the latter, Instinct. He maintains the specific difference of Instinct and Reason or Intelligence with great force and clear ness; indeed, there seems nothing to find fault with in his statements here, except that he places the seat of Intelligence in the cerebral nervous system, and of Instinct in the ganglionic, and thus is forced to deny Intelligence altogether to insects, whereas we have seen that Huber's observations plainly show the bee to have the capacity of varying its means in accomplishing the end in view when the circumstances vary; and this surely cannot be distinguished from Intelligence. Also he discusses, with perfect strictness of reasoning, the hypothesis of a very celebrated naturalist, no less than M. Lamarck, and, I must say, refutes very satisfactorily the theory of my most learned and worthy colleague, for whom we all must feel the

most profound respect. He had been induced to suppose that Instinct results from the habits originally acquired by animals adapted to the circumstances in which they found themselves placed at the beginning of the creation, and that these habits occasioned an adaptation of their structure to particular operations, as well as a constant capacity and desire to perform them. Now, my only objection to M. Virey's refutation of this theory, which is merely the exploded doctrine of appetencies in a new form, is, that it requires no such elaborate answer to overthrow it. For what do we see in all nature which in the least entitles us to suppose any animal at any period to have had the power of altering his bodily structure, creating one part and altering another according to his wants? Besides, if animals, at their first creation, had so much power and so much intelligence as this theory supposes, why should this all cease and leave them only possessed of blind Instincts now? The reasoning, however, of M. Virey is sound, and does much credit to his acuteness.

A. But have you found, in his volumes, no facts; nothing to place among the phenomena which we are collecting previous to resuming our discussion respecting the faculties of brutes?

B. Very little; and that so wrapped up in declamation, and so disfigured with figures (if I may thus speak), that there is no small difficulty in seizing hold of it. What he says of the architecture of squirrels, marmots, rats, and some other rodents, is new to me. I had only been aware of the beaver, among this tribe, as remarkable for ingenuity. But it seems these others excel all animals in digging subterranean dwellings; they make com-

partments or chambers, which they line with clay, and cover with a roof from the weather; in some of these chambers they stow vegetables, which they previously dry in the sun; others they use for the reception of their young; in others they sleep. He brings together some curious instances of swift and long-sustained flights of birds. Thus the smallest bird, he says, can fly several leagues in an hour; the hawk goes commonly at the rate of a league in four minutes, or above forty miles an hour. A falcon of Henry II. was flown from Fontainebleau, and found, by its ring, at Malta next day. One, sent from the Canaries to Andalusia, returned to Teneriffe in sixteen hours, a distance of nearly seven hundred miles, which it must have gone at the average rate of twenty-four miles an hour. Gulls go seven hundred miles out to sea and return daily; and Frigate-birds have been found at twelve hundred miles from any land. Upon their migration he states, as a known fact, that Cranes go and return at the same date, without the least regard to the state of the weather, which shows, no doubt, if true, a most peculiar instinct; but these, and, indeed, all facts which we find stated by a writer so addicted to painting and colouring, must be received with a degree of suspicion, for which no one but M. Virey is to be blamed. The accounts, however, of the swiftness of birds, I can well credit, from an experiment which I made when travelling on a railway. While going at the rate of thirty miles an hour, I let fly a bee; it made its circles as usual, and surrounded us easily. Now, if there was no current of air or draught to bear it along, this indicated a rate of ninety miles an hour; and even allowing for a current, the swiftness must

have been great. I should, however, wish to repeat this experiment before being quite sure of so great a swiftness in so small an insect.

A. Have you given all your gleanings from this work?

B. I should, perhaps, add these two. We find in it a curious passage from an old Spanish author of the seventeenth century, giving a quaint and lively account of the sagacity of the beggars' dogs at Rome; and we also find the titles of some German works on the faculties of brutes, which are truly curious, and show how great a degree of attention that laborious people have paid to the subject, but, at the same time, betray not a little of the characteristic boldness and enthusiasm of their speculations.

A. I conclude you have never seen more than these titles in this book?

B. Never; and I really should wish to see the works themselves. One is *Mayer de peccatis et pœnis Brutorum*, 1686, in quarto. Another, in 1725, *Hermanson de peccatis Brutorum;* this, however, is printed at Upsal. A third is *Schrœder de Simulacris virtutum in Brutis Animantibus*, 1691; and a fourth, *Schrœder de Brutorum Religione*, 1702. Then, it appears that one Drechsler wrote, in 1672, a *Dissertation on the Speech of Animals*, and Meyer and Martin, not to be outdone, followed this up a few years after, the one with a *Treatise on the Logic of Animals*, and another with one *De Animalium Syllogismo*.

A. Does the Spaniard give any curious particulars of dogs?

B. Not perhaps any that surpass what we have been stating from facts known among ourselves.

But his account is diverting enough. "The blind-man's dog," says he, "will take him to the places where he may best hope to get his alms, and bring him thither through the crowd by the shortest way and the safest; nay, he will take him out of the city some miles to the great church of St. Paul, as you go to Ostia. When in the town he cometh to a place where several ways meet, and with the sharpness of ear that the blind have, guided by some sound of a fountain, he gives the string a jerk by either hand, straightway will the poor dog turn and guide him to the very church where he knows his master would beg. In the street, too, knoweth he the charitably-disposed houses that be therein, and will lead thither the beggar-man, who, stopping at one, saith his pater-noster; then down lieth the dog till he hear the last word of the beadsman, when straight he riseth and away to another house. I have seen myself, to my great joy, mingled with admiration, when a piece of money was thrown down from some window, the dog would run and pick it up and fetch it to the master's hat; nor, when bread is flung down, will he touch it be he ever so hungry, but bring it to his master, and wait till he may have his share given him. A friend of mine was wont to come to my dwelling with a great mastiff, which he left by the door on entering; but he, seeing that his master had entered after drawing the string of the bell, would needs do likewise, and so made those within open the door, as though some one should have rung thereat."

A. Upon my word, you have been amusing yourself with making the old Castilian speak in old English.—But now, I think, we may be said to

have gone at sufficient length into the facts, and to have gathered together a collection large enough for our purposes of speculation—nor have we perhaps much more to do with this in that way. For can any one rationally doubt that they evince in these brutes some faculties at least approaching in kind to our own—nay, and to such of our own as we are wont to prize the most, and to be the proudest of? No blind impulse of a mechanical kind, no mere instinct, or feeling, or operative principle, apart from knowledge, experience, learning, even intention,—can surely account for the things we have just been considering as done by animals—and one example, and an ordinary one, is as good as a thousand. The cat opening a door from observing men do so before it; or the bird, from its own observation of the effect produced by solid bodies, sunk in water, raising the water by throwing in pebbles; or letting muscles fall to break the shells—these things surely argue a thinking and a reasoning process.

B. There seems little doubt of this; however, we may perhaps adjourn the further discussion, as we no longer require to be among our books, but may take our walk out in the sun, which is far from disagreeably hot to-day.

A. I have no kind of objection, and will meet you on the Terrace as soon as I have written my letters.

BOOK OR DIALOGUE IV.

ANIMAL INTELLIGENCE.—(Theory.)

We accordingly finished our letters, and prepared to go out and walk about in the sunny exposure, which a north-west wind made agreeable, as in the north it often does, even at this season—" calceis et vestimentis sumptis, placitum est ut in aprico maxime patente loco conveniremus:*"—where, as we walked about, he began in continuation of his last remark.

A. I know not why so much unwillingness should be shown by some excellent philosophers to allow intelligent faculties, and a share of reason, to the lower animals, as if our own superiority was not quite sufficiently established, to leave all question of jealousy out of view, by the immeasurably higher place which we occupy in the scale of being, even should we admit the difference to be in degree rather than in kind; because when the difference of degree becomes so vast, there is hardly any more chance of encroachment or confusion, hardly any more likeness or comparison, than if the difference were radical and in kind. Some writers, as D. Stewart, really seem to treat the question as one of an exciting nature, and almost to regard the purity

* "Having taken our boots and greatcoats, we chose to meet in an open and sunny exposure."—Cic. De Repub. lib. i. cap. 12.

of religious belief as involved in the controversy. How is this, and why should it be?

B. It is possible that the origin of the feelings shown by those good and able men, resembles that of Descartes' absurd theory, of brutes being like machines, which, as far as he holds it. he avows to have proceeded from the notion that unless they are so, their souls would be immortal. But another reason may be assigned. The sceptical, or free-thinking, philosophers always lowered human nature as much as possible. They regarded it as something gained to their arguments against religious belief, if they could show the difference to be slighter than is supposed between men and brutes; and that there is a chain of being from the plant, nay almost from inorganic matter, up to man. They seem to have had a confused idea that this helped them even to account for the constitution of the universe, "without the hypothesis of a Deity," as Laplace is said to have termed it when Napoleon questioned him on the remarkable omission in the 'Mécanique Céleste.' Thus much is certain in point of fact, that those philosophers, and especially the French school, were fond of lowering the human intellect by raising that of animals; and while the priests were lavish of their admission that our moral nature is utterly corrupt but claimed for our intellectual capacity to be only a little lower than the angels, the society of the Encyclopédie, and the coterie of Baron d'Holbach were fond of levelling the intellectual distinction between immortal and confessedly mortal beings, though they denied the moral depravity of their race with perhaps no very strict regard either to the evidence of their consciousness or of their

observation. It thus appears that this theory of a difference in kind is found in company with that of scepticism, just as some other theories are usually coupled with it also; for example, the selfish system,—philosophical necessity,—expediency,—materialism,—all of which are held by Hume, Voltaire, Helvetius, Diderot, and other free-thinkers; yet all of which are also held by some as determined believers as any that are to be found in any church. Priestley, for instance, held all these doctrines, and Paley all but the last. Hume's opinion on the reason of brutes cannot be doubted from some accidental remarks interspersed in his writings. Helvetius, a materialist and sceptic both, has explicitly stated that if the arm of man had chanced to terminate in the foot of a horse, he would still have been found wandering about as the tenant of the woods.* The company in which the opinion has been found has thus greatly disinclined pious men towards it. Professor Robinson, in his attacks on the French school, is nowhere more severe upon them than where he impeaches them of endeavouring to lower the dignity of human nature,† and undoubtedly such attempts may be made in a manner to hurt the interests both of religion and of morals.

A. Has not Lord Monboddo given great offence of the same kind, and in the same quarters?

B. Possibly he has; although from his station as a judge, and a man of most loyal political opinions, and also from his being an orthodox believer, at least as far as professions go, he has been less blamed than the rest. He was an admirable Grecian, such as in modern times Scotland has very rarely pro-

* De l'Esprit. † Proofs of a Conspiracy.

duced: and there is an infinite deal of ingenuity and subtlety as well as learning in his writings, with a constant display of most correct taste in judging of the ancient controversies. But his theory has subjected him to great ridicule, not so much from his holding that there is a gradation in the whole scale of beings, and that the mental faculties of man are found in the minds of brutes, as from his denying any specific difference even in body; and holding that originally men were fashioned like monkeys, and lived like them wild and savage.

A. I could much more readily understand this doctrine giving offence and scandal as heterodox, than the other; for it seems not very easily reconcilable either to our religion or indeed to almost any other received among civilized nations.

B. I consider it a thing just as little supported by the facts, as it is repugnant to all known systems of theology. But my objection to it is really not founded upon its tendency to lower human nature. On the contrary, I doubt if it does not rather exalt our faculties beyond all the ordinary doctrines, and draw a broader line of distinction between us and the lower animals than that which it was intended to efface. For surely if we have not only by our intelligence made the great progress from a rude to a refined state—from the New Zealander to Laplace, and Newton, and Lagrange—but have also, by the help of the same faculties, made the progress from the state of monkeys and baboons, while all other animals are the same from one generation to another, and have made not a single step for sixty centuries, and never have attempted in a single instance to store up for after-times the

experience of a former age, our faculties must needs be immeasurably superior to theirs. In short, the only question is as to the nature of the difference.

A. I can well suppose a difference merely in degree sufficient to explain any diversity of condition or result. We have only to compare individual men together to perceive this. It is admitted that reason, nay, that the power of forming abstract ideas, as well as drawing inferences from premises, is possessed by persons whom yet you shall in vain attempt to teach the simplest mathematical demonstration. Then their faculties only differ in degree from those by which Pascal learnt geometry without a master or a book, and Newton discovered Fluxions, and Lagrange and Euler the Calculus of Variations. It may truly be said, that there is no difference in kind which could make a greater diversity in the result.

B. It may indeed be truly so said; but it may also be added, that there is not a greater difference, call it in kind or in degree, between the person whose obtuseness you have supposed, and a sagacious retriever, or a clever ape, than between the great mathematicians you have named, and that same person. Locke, whose calmness of understanding was equal to his sagacity, and never allowed his judgment to be warped by prejudice, or carried away by fancy and feelings, seems to have held this opinion, and indeed to have allowed some reason to animals. "There are some brutes," he observes, "that seem to have as much knowledge and reason as some that are called men;" and he goes on to say that there is such a connexion between the animal and the vegetable kingdom,

as makes the difference scarcely perceptible between the lowest of the one and the highest of the other.

A. You quoted Addison's paper upon Instinct yesterday, in proof of his taking the Newtonian view of the subject. What does he say as to the Reason, and generally the Intelligent faculties, of animals?

B. He is, as you are aware, no very great reasoner; insomuch, indeed, that I have known persons made converts to Deism, or rather from Christianity, by reading his most feeble treatise on the Evidences. One man of great virtue, learning, and ability confessed as much to me. Accordingly, he is very wavering and inconsistent on this subject also, and encounters it with prejudice. At one place he says, reason cannot be the cause of brutes acting as they do; and then, after seeming to deny it, he only adds a kind of admission that they have reason: "for," says he, "were animals endued with it to as great a degree as man," &c. And again, in the same paper, he seems to deny it altogether. "One would wonder to hear," he says, "sceptical men disputing for the reason of animals, and telling us it is only our pride and prejudices that will not allow them the use of that faculty." This is exactly the notion to which I was a little while ago imputing the unwillingness of so many reasoners to allow brutes their fair share of intelligence. You see Addison considers it the natural course of a sceptic; yet surely Locke was as firm a believer as himself, and certainly a far more reflecting and intelligent one.

A. Perhaps we had as well consider, before going into the question, by what kind of logic the

argument is to be conducted, by what sort of evidence we are to try the cause.

B. I presume there can be no doubt here. We must examine it according to the rules of inductive science. The facts are before us. Some we gather from observation—those relating to animals; some, as those respecting the nature of the human mind, we ascertain by our own consciousness, or at least chiefly by that, though in some sort also by observing other men's conduct, and communicating with them; but having no means of communicating with animals, we are reduced to our observation merely; and then we naturally draw the inference that, because the same things done by ourselves would be known by us to be done from certain mental powers, therefore we ascribe those powers to the animals. This conclusion as to ourselves is certain, because we know and feel it to be so by our own consciousness. With respect to animals it is not nearly so certain, because we cannot either enter into their minds, as we do into our own, or communicate with them, as we do with our fellow-men. Nevertheless, by varying our observations on them, by making experiments on their faculties, by placing them in new and arbitrary combinations of circumstances, we can reduce the chances of error to a very small amount, and render our inferences as highly probable as most of the propositions of contingent truth are.

A. It is not, however, necessary that we should now go into an investigation of the nature of the human faculties. Our researches are in their nature comparative only.

B. Certainly; and therefore, agreeing with you, I would begin by laying down this position, that

all we have to do is to grant or to deny the existence of certain mental faculties, and to ascertain the meaning of the terms which we employ in expressing these. Whatever those faculties may be in us, all we are now to consider is, whether or not the brutes have the same, or in any degree.

A. I think it quite right and really for our safety, in conducting the inquiry, to lay down a second preliminary principle or caution, namely, that we have no right to argue from the mere effects produced by certain endowments, or by any given combination or modification of these. Thus, when we see what has been achieved by man, and contemplate the extraordinary monuments raised by his industry, his activity, and his intelligence, and the power which he has acquired over the operations of nature, and of all other animals, profiting so largely by both, and when we compare this with the feeble state of those animals, their having no accumulation of either knowledge or possessions, and gained nothing upon man or by man, we are drawing a contrast which really proves nothing; because it is just as easily accounted for by supposing the two classes extremely different in degree, as by assuming that they differ in the kind of their faculties. Thus to take a common instance, and one which Adam Smith himself gives as marking a great difference between us and the brutes, they have no appearance of barter; but if barter arises from comparing ideas together, and forming a conclusion from the premises, and if, from other facts, animals appear to possess that power, there being no positive barter only shows that their judgment or reasoning faculties are weaker than ours, or that for some other reason, it is immaterial to

the argument what, they have not acquired that particular result of the reasoning faculty.

B. I entirely agree in this general position, holding that the neglect of it has been one main cause of the errors into which philosophers have fallen on this question; I must, however, doubt the correctness of the position, that the brutes are wholly ignorant of barter. No one, as Smith says, ever saw one dog barter a bone with another. But many of the operations of both dogs and horses in dividing their labour, and of insects, as ants, in helping each other, seem referable to a principle not to be easily distinguished from barter. The division of labour is clearly to be observed among them. Of course I do not mean that comminute division by which bees work together, and in which they incalculably excel ourselves; for that we have classed as instinctive and unintentional, and therefore it cannot enter into our present argument. But horses plainly help one another in drawing, and take different parts of the work; so do dogs in the chace. However, to leave no doubt about it, and allowing beavers to act instinctively, the wild horses sleeping and watching by turns is a clear and unequivocal instance of the division of labour. But I admit your position—that if anything which is the result of a faculty, proved already to be one of the animal mind, is not possessed by them, this is no argument against their having that faculty. It may lead us to be the more cautious in examining the proofs by which their possession of the faculty is established: but that is all. Indeed, such distinctions are taken upon no more philosophical ground than he would have for his classification who should make two divisions of metals or of water, one the

solid, and another the fluid, accordingly as they had different temperatures.

A. I hold it to be a part of the same preliminary position, that if brutes are shown to possess any given simple faculties, their not having the power of doing things only to be accomplished by combinations of these simple powers, does not impeach the proposition, already established, of their having those simple powers. For it would only show that they have not the combination, though they may have the separate powers. Does any other proposition occur to you as convenient to be laid down in the outset?

B. I should say this, which is perhaps rather a corollary from the last, that we must carefully distinguish between simple and composite faculties, as they are called. Indeed, I deny the accuracy of this form of speech, and I believe it tends much to error in metaphysical speculations. No system of psychology, ancient or modern, sanctions it; neither those of Hartley, Priestley, Berkeley, nor that of Reid and Stewart and Brown, although I think it has been much encouraged by the speculations of these last, and their separate treatment of our mental powers under distinct heads, how necessary soever this was for the elucidation of the subject. The mind being one, and entire, and invariable, without parts or composition, acts always as one being. It recollects, praises, judges, abstracts, imagines; and when you say that it exercises a compound, or complex, or composite faculty, as for example, the imagination, you only mean that it first exerts one faculty, then another, and then a third. We never should call the process by which chemists bleach vegetable substances a composite

operation, because they first make oxymuriatic gas, then mix lime with water, then, by agitation of the water exposed to the gas, cause lime to combine, and then expose the vegetable fibre to this compound liquor; we say that these are so many successive operations performed, and not one complex operation. And so imagination is not one compound faculty, nor is imagining one complex operation of the mind. But that mind in succession remembers, abstracts, judges or compares ideas, and reasons or compares judgments—and the whole four successive operations form imagination; to which you may add the further operation of taste, which, rejecting one and selecting other results of imagination, produces the fruits of refined or purified fancy; if indeed this taste itself be anything but a sound exercise of judgment—a judgment refined by experience, that is, by constant attention to what is pleasing, and what disagreeable. The rapidity with which all these separate operations are performed by the mind, neither prevents them from being in succession and separately performed, nor at all shows the mind to have composition or parts. Giving names to certain combinations, or rather successions of operations, and not to others, may be correct; but it must be admitted is somewhat capricious. We talk of imagination as if it were one operation, though it is many; and yet we give no separate name to several other successions as rapid of our mental operations. So as to our moral feelings. We speak of conscience as one; yet it is, as Smith describes it, a succession (he says a compound) of several, among which pity for the party injured, and fear of the consequences to ourselves, are the chief. Yet we give no name

to the reflection on past enjoyments, which is as quick a succession of several emotions,—namely, recollection, comparison of the present, and sorrowing for the contrast. However, as regards our present purpose, the simplest part of the proposition is, that any given simple faculty or single operation of the mind being found to be possessed by animals, the circumstance of their not possessing the compound exclusively, or several combined, or a successive operation of different faculties, is no proof against their having the simple ones. Thus, if they have no fancy, it is no proof that they have no memory or judgment; because they may have these without having abstraction, which is one of the faculties that go to make the imaginative process. But it is also no proof of their being without abstraction, and all the other simple or single faculties; for it only proves that they have not the power of using these faculties together, or rather in quick succession, and for the same joint purpose. And should they have the simple or single, without having the compound faculties or processes, this would again argue no specific difference, but rather a diversity of degree.

A. I think these preliminary positions not only have cleared the ground for us, but helped us a good way on our journey. There appears hardly much more to reason about now. The subject has been a good deal enveloped in mist and smoke, from confusion of ideas, and from prejudice and high feeling. These being blown away, it seems pretty clear what the structure is that we are to examine.

B. Before going to the brute faculties, let us just cast a glance over the faculties which have been enumerated as belonging to ourselves, and

see if they should not be a little simplified—Sensation, Perception, Consciousness, Memory, Abstraction, Imagination, Judgment, Reasoning, to which have been added Taste and the Moral Sense; and Mr. Stewart thinks these not enough, adding among others, the power of connecting general or abstract signs with the things signified. Now suppose we admit the correctness of calling a state of mind in which it is purely passive an active power or faculty, as Sensation, which is merely the effect produced upon the mind by the operation of the senses, and involves nothing like an exertion of the mind itself, any more than receiving a hurt or a gratification passively is any exertion of the body, although the operation whereby that reaches the mind may be termed bodily exertion; then it will follow, and not otherwise, that Sensation is a faculty. But Perception is no doubt an active exertion of the mind. *Memory* differs from Recollection as Sensation does from Perception. The state of mind in which one idea calls up another, or a present state of mind influenced by a past state, is Memory. The exertion by which the mind voluntarily induces the present state from the past, is Recollection. The one is the *sensation*, the other the *perception* of the past, as sensation and perception are of the present.

A. Is not Perception an inference from Sensation? I have the sensation of solidity or of smell, and I perceive either the solid, resisting body, and the odorous body, or I perceive the solid or odorous quality, that is, I infer a being from the sensation, or I infer a quality; the former seems a simple inference, the latter an inference coupled with an abstraction.

B. I do not incline altogether to this opinion; but at any rate it will not apply to Memory and Recollection; for Recollection is not an inference from Memory; it is an effort by which the mind throws itself into the state into which it might have been brought by the former ideas recurring of themselves. In Perception we do not voluntarily throw the mind into the state of Sensation; we draw an inference from that sensation according to your theory. But I think it pretty clear that there is something between the sensation and the inference —the simple apprehension and the conclusion drawn. The latter is clearly an inference that an external being exists which created the sensation and the perception. But I think there is also a perception upon the sensation, and which cannot certainly exist without it. However, be this as it may, to our present purpose it makes no difference, except as far as there can be no doubt of the mind being in a much more passive state in the two conditions of feeling and remembering than in the other two of recollecting and perceiving.

A. Then of Imagination we have already disposed. It consists of the successive, though rapidly succeeding operations of other faculties whereby we create or combine new ideas that had no previous existence, abstracting the qualities of one object to clothe another with them. But Abstraction we may allow to be a simple operation and one of the most important. What do you make of two that I do not remember you to have named, Attention and Conception?

B. I omitted them purposely. I can see really nothing in Attention but the degree in which certain other faculties operate. It is only the inten-

sity with which I perceive. Possibly there may be some good from considering it as the difference between Perception and Sensation: in the latter case the mind passively receives the impression of the senses; in the former it fixes itself steadily upon those impressions, so as to feel them by a voluntary effort more acutely. As for Conception, which used formerly to be called Simple Apprehension, it is only the forming ideas of objects neither presented by the senses nor by the imagination; and I am unable to separate it from Memory and from Abstraction—from memory as far as it deals with former ideas, from abstraction as far as it deals with quality apart from the objects remembered or imagined.

A. Then Judgment being the comparison of ideas, and Reasoning the comparison of judgments, that is, of the ideas arising from the former comparison, may be set down as one faculty—that of Comparing—and I conclude you make quick work with Taste and the Moral Sense, of which the one gives us preferences among objects of mental gratification, and the other among objects of moral approbation?

B. They are both evidently exercises of the judging and reasoning powers,—say the comparing powers, according to two standards,—the one the sense of beauty or fitness, of what is pleasing or agreeable; the other, the sense of what is just and right. But whether this last sense is natural or acquired, and how acquired, is a question that has long divided philosophers, and which will very certainly never be determined. Nor is it more easy to determine the other, which is quite a kindred one, how it is that our taste is formed, and

whether it be natural or acquired. All that we can say on this subject is, to remark the little practical importance which belongs to either question, and to state that, as far as our present discussion is concerned, the only faculty involved in either the one or the other is that by which we compare different ideas.

A. Our enumeration then of mental faculties seems to resolve into Perception, active or passive; Memory, active or passive; Consciousness, Abstraction, and Comparison; then how do we place animals as to the first?

B. Clearly no animal, nothing having life, can be conceived to exist, without Passive Perception at all events, and hardly any without Active Perception also. Consciousness too seems a necessary quality of every mind; it is the knowing one's own existence; so Memory of the passive kind must exist in every mind; without Consciousness and Memory no animal could know its own personal identity; and no acts could be done by it upon the supposition of that identity. With respect to Active Memory and Conception, if this is to be held a separate faculty, it is implied in Comparison, or in judgment and reasoning; so that our inquiries come to be confined within sufficiently narrow limits. Do the lower animals possess Abstraction and Comparison? I will at once begin with Abstraction, because it is the power most generally denied to brutes; and this arises, as I conceive, from an ill-grounded notion of its nature, and from a supposition that it is a faculty of a far more refined nature, subservient to operations of a much more difficult kind, than the truth will warrant us in affirming. The truth appears to be, that there

are, if not two kinds of Abstraction, an active and a passive, yet certainly some degrees of Abstraction so easy and even unavoidable, that we can hardly conceive almost any mind incapable of forming them. But on the other hand, the very highest and most difficultly attained reach of human thought is connected with Abstraction. Observing this, philosophers have passed all under one name, and because the brutes could not conduct algebraical investigations or metaphysical reasonings, have denied them all power whatever of forming abstract ideas.

A. To a certain degree this is no doubt true. The abstraction by which we reason upon m and n or x as only numbers; deal with x the unknown quantity, multiplying it and speaking of m times x, or dividing it and speaking of one n^{th} part of x, is no doubt a high and refined reach of thought; but so is the forming to ourselves an idea of abstract qualities; indeed I know not if, when we reason about m and x, we do more than mechanically deal with the letters; whereas in reasoning of colour or smell as abstracted from the rose with which we always have seen them conjoined, and forming to ourselves the idea of something in the abstract which we have only ever seen in the concrete,—of some ideal existence of which in actual existence we have never known anything, nor can know,—we really appear to go a step further. Now do you maintain that Abstraction is ever otherwise than a difficult and painful operation?

B. First of all be pleased to observe that many philosophers altogether deny, even to man, the power of forming abstract ideas. The dispute of the *Nominalists* and *Realists*, so well ridiculed by Swift, or rather by Arbuthnot in Scriblerus, is as

old as metaphysical inquiries, under one name or another. They consider it impossible for us really to form these abstractions, and hold that we only are using words and not dealing with ideas, just as you seem to think we do in algebraical language. Mr. Stewart is among those who conceive that we think in language. My opinion, if against such venerable authority I may venture to hold one, is different. I think we have ideas independent of language, and I do not see how otherwise a person born deaf and dumb and blind can have ideas at all; which I know they have, because I carefully examined the one of whom Mr. Stewart has given so interesting an account. Indeed he has recorded the experiment of the musical snuff-box which I then made upon this unhappy but singular boy. But next I am to show you that abstraction independent of algebra, or metaphysical reasoning altogether, is neither difficult nor painful. Without Abstraction we cannot classify in any way, or make any approach to classification. Now I venture to say that no human being, be he ever so stupid, is without some power of classification, nay, that he is constantly exercising it with great care, and almost unavoidably, and acting upon the inferences to which it leads. He can tell a man from a horse. How? By attending to those things in which they differ. But he can also tell a stone from both, and he knows that the stone is different from both. How? By attending to those things in which the two animals agree, and to those things in which they differ from the stone. So every person having accurate eyes and the use of speech can call a sheet of paper and a patch of snow both white; a piece of hot iron and of hot brick both hot. He has therefore the idea in his mind of colour and of heat

in these several cases, independent of other qualities, that is, abstracted from other qualities; he classifies the white bodies together, independent of their differences; the hot bodies, independent of theirs; and he contrasts the white metal with the white snow, because they differ in temperature, without regarding their agreeing together in colour. All this is Abstraction, and all this is quite level to the meanest capacity of men. But is it not also level to brute intellect? Unquestionably all animals know their mates and their own kind. A dog knows his master, knows that he is not a dog, and that he differs from other men. In these very ordinary operations we see the animal mind at one time passing over certain resemblances and fixing on differences; at another time disregarding differences and fixing only on resemblances. Nay, go lower in the scale. A bull is enraged by a red colour, be the form of the body what you please. A fish is caught by means of a light, be it of any size or any form.

A. These things which you last mention are mere sensations. The red light or the flame impresses the retina and affects the animal's sensorium, his brain—irritating the quadruped, and attracting the fish.

B. What then? Other sensations pass to his mind through his senses at the same time. He has the sensation of form as well as colour; yet he passes this entirely over, and only considers the colour. However, take those cases in which animals are attracted to certain places. They are hungry and go to a certain field to eat, without the least regard to its position or its shape; because it agrees with other fields in bearing the food which

the beast is in quest of. Flies approach the light because they believe it to be the open air where they wish to go. So the bird never throws stones into a river or puddle to raise the water; but it does throw them into the ewer. It abstracts water from the thing containing it; and could not reason upon the effects of the operation without a process of Abstraction. Indeed, upon the footing on which you would put it, I know not that all our own abstract ideas may not in the end be resolved into sensations and their immediate consequences. I know of no evidence that you have of our abstract ideas being formed in any other way, except on our consciousness, and our continual communication of ideas and experience through speech. In the case of the brute we have all the same phenomena, and, excluding the operation of blind Instinct, we are forced to the like conclusions.

A. I think we may go a step further; have not animals some kind of language? At all events they understand ours. A horse knows the encouraging or chiding sound of voice and whip, and moves or stops accordingly. Whoever uses the sound, and in whatever key or loudness, the horse acts alike. But they seem also to have some knowledge of conventional signs. If I am to teach a dog or a pig to do certain things on a given signal, the process I take to be this. I connect his obedience with reward, his disobedience with punishment. But this only gives him the motive to obey, the fear of disobeying. It in no way can give him the means of connecting the act with the sign. Now connecting the two together, whatever be the manner in which the sign is made, is Abstraction; but it is more, it is the very kind of Abstraction in

which all language has its origin—the connecting the sign with the thing signified; for the sign is purely arbitrary in this case as much as in human language.

B. May we not add that they have some conventional signs among themselves? How else are we to explain their calls? The cock grouse calls the hen; the male the female of many animals The pigeon and the fieldfare and the crow make signals; and the wild horse is a clear case of signals. All this implies not only Abstraction, but that very kind of Abstraction which gives us our language. It is in fact a language which they possess, though simple and limited in its range.

A. As to the power of comparing, what is commonly called Reason, *par excellence*, comprising Judgment and Reasoning, this needs not detain us very long. The facts here are not well liable to dispute. There is no possibility of explaining the many cases which we began by going over without allowing this power. They all prove it in some degree. Several of them show it to exist in a very considerable degree. The acts of some birds and monkeys cannot be accounted for by Instinct; for they are the result of experience; and they are performed with a perfect knowledge of the end in view; they are directed peculiarly to that end; they vary according as the circumstances in which they are performed alter, and the alteration made is always so contrived as to suit the variation in the circumstances. Some of these acts show more sagacity, according to Mr. Locke's observation, than is possessed by many men. The existence of a comparing and contriving power is therefore plain enough. And on the whole I conceive that a ra-

tional mind cannot be denied to the animals, however inferior in degree their faculties may be to our own.

B. That inferiority is manifestly the cause why they have made so little progress, or rather have hardly made any at all. Some little is proved by such facts as Mr. Knight has collected, but they are only exceptions to the rule which has doomed them to a stationary existence. This difference, however, is merely the result of the inferior degree of their mental powers, as well as the different construction of their bodily powers. The want of fingers endowed with a nice sense of touch is an obstruction to the progress of all, or almost all, the lower animals. The elephant's trunk is no doubt a partial exception, and accordingly his sagacity is greater than that of almost any other beast. The monkey would have a better chance of learning the nature of external objects if his thumb were not on the same side of his hand with his fingers, whereby he cannot handle and measure objects as we do, whose chief knowledge of size and form is derived from the goniometer of the finger and thumb, the moveable angle which their motion and position give us. Insects work with infinite nicety by means of their antennæ; when these are removed they cease to work at all, as Huber clearly proved. Clearly this different external conformation, together with their inferior degree of reason, is sufficient to account for brutes having been stationary, and for their being subdued to our use, as the Deity intended they should, when He appointed this difference. To argue from the complex effect of all the faculties, bodily and mental, in giving different progress or power to our race and to theirs, and to

infer from this difference that there is an essential and specific diversity in our mental structure, nay that they have not one single faculty the same with ours in kind, is highly unphilosophical. It is indeed contrary to one of the fundamental rules of philosophizing, that which forbids us needlessly to multiply causes. For we are thus driven to suppose two kinds of Intelligence, human and brutal, and two sets of faculties, a Memory and a Quasi Memory, as the lawyers would have it—an Abstraction and Reasoning, properly so called, and something in the nature of Abstraction and Reasoning, but, though like, yet not the same.

A. There is one matter to which we have not as yet adverted, but, after having considered the intelligent as well as instinctive powers, we may now as well do so. I mean the diversity in the operations of the latter, and the perfect sameness of the former—a sameness in all the operations of any given individual animal, and likewise of each of the species.

B. This is well worthy of consideration. When trying to explain instinctive operations upon the hypothesis of an intelligent principle acting under the impulse of sensations, I found in this perfect sameness and regularity of its operation a considerable difficulty, though not perhaps an insuperable one, not certainly so great a difficulty as those we have considered.

A. How did you endeavour to explain, on that hypothesis, the regularity of Reason or Intelligence?

B. The absolute sameness of moral and intellectual character, and the limited sphere of ideas and events, will account for much. We see far less diversity of action and speech among peasants of a very confined knowledge and very limited range of

pursuits, than among persons of a higher degree of education and superior station in life. But still there is a great diversity. Taking, however, two men of most perfect resemblance in all their faculties, and all their feelings, similarly constituted in both body and mind, they would probably act nearly if not entirely alike. Whatever made one do a thing would make the other, and we must suppose them to be placed in perfectly similar circumstances, so that the same things would happen to both. Chance is here to be put out of view; because it only means ignorance of motives and circumstances, and assumes a diversity in these unknown to us, which by the supposition is here excluded. Suppose these two individuals thus placed in like circumstances as to food and building materials, why should they eat differently, or make different habitations? What is there to make the one choose a plant which the other does not choose? or form a hut in any particular different from the other? If one kind of food was nearer the one, and another nearer the other individual, they might choose differently; but this assumes that both kinds are agreeable to the constitution of their palates.

A. As long as providing for merely physical wants was their whole occupation, it is probable that both would act alike, except that, if any difficulty occurred to be vanquished, I am not at all sure of their adopting the very same means to overcome it. One might break a nut with his teeth, another with a stone, or by bruising two nuts together. But there is the same diversity in the conduct of animals where they act by intelligent principles. The general resemblance of their proceedings is explained by the consideration you are

stating in the case you put of the boys. Their instinctive operations would never vary in the least particular. When they came to reason, or speculate, or converse, the sameness would probably cease. It seems inconsistent with imagination and with free will; yet of this I speak doubtingly, considering the hypothesis you have made of faculties and feelings perfectly alike in all respects.

B. Certainly, you ought to speak doubtingly, when such is the hypothesis that is now binding us. I do not see how, even in reasoning, anything should ever come into the mind of the one that did not suggest itself to the other. But our hypothesis is not easy to remain under. Suppose, to make the case like instinct, two untaught children in different parts of the country, viz., one in China and the other here, to be placed in a situation where the same kinds of food and building materials were placed, and a variety of each, we may assume that similar tastes and constitution of mind and body would make them eat the same things, perhaps choose to shelter themselves by building rather than by going into caves, possibly to build with the same materials selected out of a number; but it is much to say that they would exactly preserve the same figure and size and proportions in the huts they made. Each would certainly make blunders, and work inartificially; and it is difficult to fancy them exactly making the same blunders, deviating from the straight line or the circle by the same quantity of aberration, and from the perpendicular by the same angle: yet the bee in China and in England makes the same angles, and forms cells with the same proportions, and raises the grub the same height from the liquor provided for its

nutriment, so as to let it have access to the liquor without incommoding or drowning it.

A. When instinct is interfered with by obstacles interposed, the animal's intelligent powers are brought into action, and then the uniformity and perfect regularity ceases. This seems to present under this head, as well as the other head of knowledge and design or intention, a sufficiently marked distinction.

B. Certainly: and it is to be observed that the more sagacious any animal is, the greater variety is perceived in his actions and habits. Thus the elephant and the dog present general resemblances throughout each species; but the instances of sagacity or reason which the different individuals exhibit are sufficiently various: whereas there is no more diversity in the ordinary working of the bee, than in the operations of crystallization, or the secretion of the sanguiferous or the lacteal system. In truth, we may compare the two cases together. Instinct seems to hold the same place in the mental which secretion and absorption do in the physical system. Intelligence or reason will sometimes interfere with Instinct, as our voluntary actions will interfere with the involuntary operations of secretion. But the instinctive operation proceeds whether the animal wills or no—proceeds without his knowledge, and beyond his design—as secretion goes on in our sleep without our knowledge and without any intention on our part. So as secretion goes on without any help from us, or any direct co-operation, Instinct works without any aid from Intelligence. But there is this difference in the connexion of will or Intelligence with Instinct, and the connexion of voluntary action with secretion—that

the Instinct seems subservient to the intelligent will far more than the secreting power is to the voluntary action. The bee, when obstructed, applies his Instinct, as it were, to overcome the obstacle, whereas we cannot alter at will the course of secretion ; we have some direct power over it, but very little.

A. One thing seems quite clear, that upon any view of this great question, whatever theory we adopt, all leaves the inference of design untouched ; nay, the more we inquire, the more we perceive that all investigation only places in a stronger light the conclusion from the facts to a superintending Intelligence.

B. Beyond all doubt it is so. The whole question is one of relations and connexions. Adaptation—adjustment—mutual dependence of parts—conformity of arrangement—balance—and compensation—everywhere appear pervading the whole system, and conspicuous in all its parts. It signifies not in this view whether we regard Instinct as the result of the animal's faculties actuated by the impressions of his senses—or as the faint glimmerings of Intelligence working by the same rules which guide the operations of more developed reason—or as a peculiar faculty differing in kind from those with which man is endowed—or as the immediate and direct operation of the Great Mind which created and which upholds the universe. If the last be indeed the true theory, then we have additional reason for devoutly admiring the spectacle which this department of the creation hourly offers to the contemplative mind. But the same conclusion of a present and pervading Intelligence flows from all the other doctrines, and equally flows from them all. If the Senses so move the animal's mind as to produce the

perfect result which we witness, those senses have been framed and that mind has been constituted, in strict harmony with each other, and their combined and mutual action has been adjusted to the regular performance of the work spread out before our eyes, the subject of just wonder. If it is Reason like our own which moves the animal mechanism, its modification to suit that physical structure and to work those effects which we are unable to accomplish, commands again our humble admiration, while the excellence of the workmanship performed by so mean an agent impresses us with ideas yet more awful of the Being who formed and who taught it. If to the bodily structure of these creatures there has been given a Mind wholly different from our own, yet it has been most nicely adapted to its material abode, and to the corporeal tools wherewith it works; so that while a new variety strikes us in the infinite resources of creative skill, our admiration is still raised as before by the manifestation of contrivance and of expertness which everywhere speaks of the governing power, the directing skill, the plastic hand. Nor is there upon any of these hypotheses room for doubting the identity of the Great Artificer of nature. The same peculiarity everywhere is seen to mark the whole workmanship. All comes from a Supreme Intelligence; that intelligence, though variously diversified, preserves its characteristic features, and ever shines another and the same.

NOTE TO THE DIALOGUES.

In Dialogue I. the Instinct of the duckling hatched under the hen and of the chicken in the oven is mentioned. The two following facts have occurred since that discussion was ended.

When a sow farrows, the pigs are expelled with some force, and to a little distance, by the action of the uterus and abdominal muscles. Each pig instantly runs up to one of the teats, which he ever after regards as his own peculiar property; and when more pigs than teats are produced, the latter ones run to the tail of some of the others, and suck till they die of inanition.

Mr. Davy in his account of Ceylon mentions a remarkable Instinct of the alligator. He saw an egg in the sand just ready to crack, and broke it with his stick. The animal came out, and made at once for the river. He held his stick before it, and immediately the reptile put itself in a posture of defence, as an adult alligator would have done in like circumstances.

In Dialogue III. there is some doubt expressed as to the water-moth loading its case, if too light in the water, with a kind of ballast. The larvæ of the *Phryganea* are stated by Mr. Lyell to do this habitually, and to use fresh-water shells for their ballast. This gives rise to many masses of calcareous matter in the tertiary formations. As many as 100 small shells are found surrounding one tube. (*Principles of Geology*, vol. ii. p. 232.)

In Dialogue IV. some remarks are made upon Hereditary Instincts. Mr. Roullin has related a similar instance of such Instinct in the hunting dogs of Mexico. Were they to attack the deer in front, whose weight ex-

ceeds their own sixfold, they would be destroyed and have their backs broken, as happens to other dogs ignorant of the manœuvre, which consists in attacking from behind or laterally, and seizing the very moment when the deer, in running, rests upon two legs. The dog then takes hold of him by the belly and throws him over. The dog of pure breed inherits this stratagem and never attacks otherwise. Should the deer come upon him unawares (from not seeing him), he steps aside and makes his attack at the proper time in the animal's flank; other dogs, however superior in sagacity and strength, make the attack in front, and have their necks broken by the deer. So too some of our English miners carried out greyhounds to hunt the hares in Mexico. The air on that elevated platform, 9000 feet above the level of the sea, is so rare that the mercury stands at 19 inches generally, and the dogs were soon exhausted with running in such an atmosphere; but their whelps are not at all incommoded by it, and hunt as easily as the dogs of the country.

Respecting the elephant, extraordinary accounts are told by military men who were in the Burmese war. They relate that when any extra task is to be performed by them, some favourite dainty is held up beforehand, and the sagacious animal, comprehending the promise of reward thus implied, exerts himself to earn it. This comes to the principle of barter as near as may be.

ON THE GLOW-WORM.

The facts relating to the light of this and other similar insects are by no means accurately known; and upon some material points able observers differ widely. Thus it was deemed very natural to suspect that some inflammable matter in a state of slow combustion caused the luminous appearance, the rather as it bears a striking resemblance to the light emitted by phosphorescent bodies. Accordingly the obvious course was pursued by different

experimenters, of exposing the insects to heat and to oxygen gas, to see if the light was increased; and exposing them to carbonic acid and hydrogen gases, to see if the light was then extinguished. Forster and Spallanzani affirm that they have tried this experiment, and found the result to accord with the theory; they assert distinctly that in oxygen gas, and on the application also of heat, the light is more brilliant, and that none is given out in hydrogen and carbonic acid gases. But Sir H. Davy found that the light continued in the latter gases not sensibly diminished, and that oxygen did not increase its brightness;* Mr. Macartney observed the light in vacuo and under water,† while Dr. Hulme found that it was extinguished in hydrogen, carbonic acid, and nitrous gases, although he could not perceive that oxygen gas increased.‡ There seems reason to suspect that these able men made their experiments on different species of the insect, and that the animal or vital powers which regulate the secretion, or the use of the luminous matter, were affected by the gases applied. For it is admitted on all hands that the living insect has a power of extinguishing the light independent of any mechanical operation by which it may cover over the shining part; and although the fire-fly has that part usually covered with its wings, and therefore only shines when flying, the glow-worm's light is constant, unless she restrains or extinguishes it by a voluntary act.

That some luminous matter is secreted by the insect there can be no doubt. The fact that boys in South America rub their faces with bruised fire-flies, to make them shine, is asserted by travellers; and this seems to render it probable that the glow-worm likewise secretes such an oil. But the experiments of an able chemist, Mr. Murray, have set this question at rest. He examined a box in which glow-worms had been kept, and found several luminous specks which they had left behind them. Some of these yielded a steady light for five or

* Phil. Trans. 1810, p. 287. † Ib. 1810.
‡ Ib. 1801.

six hours. Mr. Murray says that the luminous matter is inclosed in a capsule of a transparent substance, which, when ruptured, lets out the matter in a liquid form of the consistency of cream. A French naturalist, M. Macaire, made some experiments upon this matter, the result of which differed materially in one respect from that of either Spallanzani, Davy, or Hulme; for he is said to have found that the presence of oxygen in the air prevents it from shining, a position not reconcileable with the worm shining in the atmosphere. But some of this author's experiments seem to furnish a solution of many difficulties; for their results refer the appearance to the animal functions. He found that the luminous matter is chiefly composed of albumen, and that any body which coagulates albumen destroys the shining quality; which it probably does by altering the albuminous state of the fluid. He also observed, that though a certain degree of temperature is necessary for it, a higher degree destroys it altogether; and also that common electricity has no effect in exciting it, but that voltaic electricity or galvanism does excite it. These observations, if accurate, are the most important that have been made upon this subject. They seem to indicate an immediate connection between the vital powers of the insect and its luminous quality; and they account satisfactorily for the diversity in the results of former observers, who operated upon the animal apparently without taking its vital functions into the account.

The glow-worm (Lampyris Noctiluca) is not the only luminous insect. There are several other kinds both winged and apterous. Of these the fire-fly, a species of the Elater and of the beetle tribe, has already been mentioned. Indeed all the species of the Lampyris genus are supposed to be more or less luminous. Several other species of the Elater, as well as the fire-fly, are also luminous. Some species of the Fulgaro (an hemipterous insect) shine so bright that they are called lantern flies. Of these the Fulgora Candelaria is a native of China, and the F. Lanternaria, which is two or three inches long, is a native of South America. The shining matter in these,

and all others of the genus that shine at all, is confined in a transparent bulb projecting from the head.* Two species of centipes, the Geophilus Electricus and G. Phosphoreus, also shine; the former is a native of this country, the latter of Asia.

Several theories have been formed to explain the use of this luminous quality. It is observable that some of the insects which have it are apterous in one sex while the other is winged—as the glow-worm, the male of which is a fly, the female being a caterpillar. In others, both male and female are winged. Again, some have the light always in front, and it seems not to vary in brightness, as the Fulgora. Naturalists have supposed that in these it is serviceable in discovering their prey. But it has also been suggested that defensive or protective purposes may be the final cause of the light. Insects which prey on caterpillars have been observed running round the Geophilus Electricus as if afraid to approach it.† But there is one peculiarity in the glow-worm's light which seems to sanction the commonly received opinion of its use being chiefly, if not entirely, to attract and direct the approach of the male. Not only has the latter wings, and thus is by his habits little likely to be found near the unwinged female—there is also found to be much less light emitted by the male; insomuch that at one time the female alone was believed to shine at all, until Ray corrected this error. It is also remarked that the light is the strongest when the two are together, and that in some, if not all the species, the luminous quality is confined to the time when they are destined to meet. Nor is De Geer's objection, founded on the observation that the chrysalis and larva of the species have somewhat of the same luminous quality, of much force. For as the very learned entomologists just cited, Messrs. Kirby and Spence, have well observed, this instance may easily be set down with the analogous case of males having a kind of lacteal system in some animals, including our own species. It deserves further to be remarked, that in Brazil there is a glow-worm which is

* Kirby and Spence, ii. 413. † Ib. ii. 225.

winged, both male and female, and the light given by this insect is not steady like that of our glow-worm, but sparkles or intermits. On the other hand, the fire-fly of Brazil is said to give a constant light.* But this may be owing to the greater luminousness of the tubercles in the thorax, which in the European fire-fly give so little light compared with the patches concealed by the cases (elytra) of the wings, that they seem only to shine when flying.

* Kirby, Bridgewater Treatise. ii. 366.

ANALYTICAL VIEW

OF THE

RESEARCHES ON FOSSIL OSTEOLOGY.

AND

Their Application to Natural Theology.

BY HENRY LORD BROUGHAM, F.R.S.
AND MEMBER OF THE NATIONAL INSTITUTE OF FRANCE.

ANALYTICAL VIEW

OF THE

RESEARCHES ON FOSSIL OSTEOLOGY,

AND

THEIR APPLICATION TO NATURAL THEOLOGY.

FOSSIL OSTEOLOGY.

THE great work of Cuvier stands among those rare monuments of human genius and labour, of which each department of exertion can scarcely ever furnish more than one, eminent therefore above all the other efforts made in the same kind. In the stricter sciences the 'Principia' of Newton, and in later times its continuation and extension in La Place's 'Mécanique Céleste,'—in intellectual philosophy, Locke's celebrated work,—in oratory, Demosthenes,—in poetry, Homer,—* leave all competitors behind by the common consent of mankind; and Cuvier's Researches on Fossil Osteology will probably be reckoned to prefer an equal claim to distinction among the works on Comparative Anatomy. That this great performance deserves to be attentively studied there can be no doubt.

* If English law were not a local learning merely, Fearne's work on Contingent Remainders would perhaps deserve to be thus ranked. In the eloquence of the pulpit, Hall comes nearer Massillon than either Cicero does, or Æschines, to Demosthenes.

But as its bulk, in seven quarto volumes, may be apt to scare many readers, there may be some use in giving a general account of the progress of the author's inquiries, and of the principal results to which they led him, and more particularly in showing their application to Natural Theology.

Long before his attention was called to the remains of animals found in various strata of the earth, in more superficial situations, in crevices of rocks, and in caves, he had, fortunately for science, been a skilful proficient in anatomy, both human and comparative. But the first steps of his inquiries concerning those fossil remains showed him how much he had yet to do before he could implicitly trust the received accounts of the animal structures. As regards the human subject, for obvious reasons, the knowledge possessed, and which the ordinary works of anatomy contain, is accurate enough and sufficiently minute. But it is far otherwise with the structure of other animals, and especially as regards their Osteology. Of this Cuvier found so many instances, that he began his investigations with examining minutely and thoroughly the bones of all those species which, or the resemblance of which, are supposed to have furnished the materials of the great deposits of fossil bones so abundant in almost every part of our globe. This, then, was the course which he invariably pursued; and he never attempted to draw any inferences respecting the fossil animal, until he had accurately ascertained the whole Osteology of the living species. There was obviously no other way of excluding mere fancy and gratuitous assumption from the inquiry, and making the science, of which he was really to lay the very

foundation, one of pure reasoning from actual observation, in other words, one of strict induction.

In the course of his work there are to be found striking examples of the mistakes into which former inquirers had been led by neglecting this precaution. Partly by relying on incorrect, though generally received, descriptions,—partly by undervaluing the requisite comparisons of the fossil with the known bones,—partly, no doubt, by giving loose to fancy, observing the remains discovered with the bias of a preconceived opinion, and making the fact bend to a theory — authors had committed the most grievous errors, hastened to conclusions wholly unwarranted by the facts, and often drawn inferences which the facts themselves negatived instead of supporting. Thus M. Faujas de St. Fond, a geologist of great learning and experience, but who had upon a very scanty foundation erected a dogma, that all the fossil remains belonged to animals still found alive in different parts of the earth, and set himself to deny the novelty of all the fossil species of unknown animals, conceived that he had at length himself found among those remains two animals which, if they still existed at all, could only be found in the interior and remote parts of India. Of these supposed discoveries he published the drawings, representing two fossil heads. But Cuvier, upon examination, found one of them to be exactly the auroch or bison, and the other the common ox.* A more skilful naturalist, Daubenton, describes three sets of fossil teeth, in the King of France's cabinet, as belonging to the hippopotamus; and upon examination two of these sets are found to be teeth of two

* Recherches, vol. iv. p. 108.

new and unknown animals,* and the third alone those of the river horse; and Camper, one of the greatest anatomists of his age, fell into a similar error. Upon the discovery of some fossil bones in the Duchy of Gotha, there was a general belief that they were some *lusus naturæ*, and several medical men wrote tracts to prove it. But a nearer inspection proved them to be elephant's bones.† The town of Lucern took in earlier times for the supporters to its arms a giant, from the opinion pronounced by a very celebrated physician (Felix Plata), that the bones discovered in that canton were human and gigantic, though Blumenbach afterwards examined them, and found they belonged to the elephant. Finally, Scheutzer maintained that there were remains in different places of men who had perished in the general deluge, and supported his opinion by several instances to which he referred. Upon examination these have proved to be none of them human bones; but one set are those of a water salamander, while another belong to a newly discovered animal still less resembling our species, being something between a lizard and a fish.‡ When professional anatomists and professed naturalists could fall into such mistakes as these, there is little wonder that a statesman like Mr. Jefferson, however illustrious for higher qualities, should commit a similar blunder. He drew from the fossil bones discovered by General Washington near his seat in Virginia, and to which his attention was directed by that great man, the conclusion that they belonged to an enormous carnivorous animal, which he named

* Recherches, vol. i. p. 305. † Ib. p.120.
‡ Ib., vol. v. pp. 433 and 451.

the Megalonyx. Cuvier, from a more correct examination, showed the creature to have been a sloth of large dimensions, and which fed wholly upon the roots of plants.

If these examples, and they might be very greatly multiplied, evince the necessity of a cautious examination, and of a previous attention to the Osteology of animals with which we are fully acquainted, the success of Cuvier's inquiries also shows that, with due care and circumspection, the reward of the inquirer is sure. The connexion between the different parts of the animal frame is so fixed and certain, and the species run so little into one another, that it requires but a small portion of any animal's remains to indicate its nature, and ascertain the class to which it belongs. Each small portion, so it be superficial, of bone—each little bony eminence—has its distinctive character in each species; and from one of these, or sometimes from a piece of horn, or of hoof, or a tooth, the whole animal may be determined. "If," says Cuvier, "you have but the extremity of a bone well preserved, you may by attention, consideration, and the aid of the resources which analogy furnishes to skill, determine all the rest quite as well as if you had the entire skeleton submitted to you."* Before placing entire reliance on such an induction, this great observer tried many experiments on fragments of the bones of known animals, and with a success so unvaried as gave him naturally implicit confidence in his method when he came to examine Fossil Remains.

* Recherches, vol. i. p. 52. We have used the expression skeleton; the author says animal, but manifestly, from what follows, this is incorrect.

Among those he discovered a number of animals wholly unknown, and of which no individuals have existed since the period when the authentic history of our globe and its inhabitants has been recorded. Out of the 150 which he investigated about 90 were either of new orders, or of new genera, or new species of genera still living on the earth. Consider, in respect to genera, there were in the 49 unknown species, 27 which belonged to unknown genera, and these genera amounted to seven. Of the remaining 22, 16 belonged to known genera or sub-genera; the total number of genera and sub-genera, to which he could reduce the whole of his fossil species, known or unknown, being 36. It must, however, be added, that it is very possible the remaining 60 also may be of new species; for as he only had the bones to examine, it does by no means follow that the living animal did not differ as much from the ones which have the same Osteology, as the mule, or the ass, or the zebra do from the horse, the jackall from the dog, or the wolf from the fox; for the skeletons of a zebra, an ass, and a horse, present the same appearance to the osteologist; so do those of the jackall, the dog, the fox, and the wolf; and yet the same bones clothed with muscle, cartilage, skin, and hair, are both to the common observer and to the naturalist animals of a different species or subdivision. This consideration is to be taken into the account as a deduction or abatement from the certainty which attends these researches; the certainty is only within certain limits; the fossil animals which now appear to resemble one another, because their Osteology is the same, may have differed widely when living; those which appear to have been of the same class

with other animals that yet people the earth, may yet have been extremely different; and those which now seem to be in certain particulars different from any we or our predecessors have ever known, may differ from all that live or have lived on the earth we now inhabit, in many particulars far more striking than the varieties which their bony remains present to the osteologist's eye.*

The situations in which those remains were found, and are still to be met with in greater or less abundance, are various; but they may be reduced to three classes in one respect and to four in another: to three, if we regard only the kind of place where the bones are collected and found, in other words their mineral matrix; to four, if we regard the periods at which the earthy formations were effected, and the bones of animals living then, or immediately before, were deposited. In the former point of view, the remains are found either, *first*, imbedded in strata, at greater or less depth, and of various kinds, and at various inclinations; —or, *secondly*, mixed together, and with earthy matter, in caves, and in rents or fissures or breaches formed in rocks;—or, *thirdly*, scattered more sparingly, and as it were solitarily in alluvial soil or superficial detritus, in portions of the earth, apparently while it wore its present form, and was peopled by all or most of its present inhabitants. In the latter, and the more important point of view, those remains are either found, *first*, in the beds which were deposited by the waters of a world before the existence of either human beings or the

* Mr. C once or twice adverts to this consideration; but he certainy does not bring it so prominently forward as would have been desirable.

greater number of living genera of animals—as in the copper slate of Thuringia, the lias of England, the clay of Honfleur, and the chalk—in these strata the remains of reptiles are found with extinct species of marine shells, but no vertebrated animal higher than fishes; or, *secondly*, in the strata deposited by the sea, after it had destroyed the first races, and covered the land they lived upon,—and in these beds, which at Paris lie on the chalk, are to be found only animals now extinct, and of which most of the genera and all the species differ from any we now see;—or, *thirdly*, in the strata deposited by the sea, or in fresh-water lakes,—and in these later tertiary beds are to be found animals now unknown, but resembling the present races, being different species of the same genera, or apparently of families still living, but not now inhabiting the same countries, or living under the same climates;—or, *fourthly*, in places where rivers, lakes, morasses, turf-bogs, have buried the remains of existing species; and as these changes of a limited extent have happened to the globe, constituted as it still is, those animals appear to have been for the most part identical with the animals which we still see alive in various parts of the world, at least as far as their skeletons can tell.

Paris is the centre of a most extraordinary geological district. It is a basin of twenty leagues, between fifty and sixty English miles, in diameter, extending in a very irregular form from the Oise near Compiegne on the north, to the Canal de Lory, beyond Fontainebleau on the south, and from Mantes on the Seine upon the west, to Montmirail on the east; comprehending within its circuit the towns of Paris, Versailles, Fontainebleau, Estampes,

Meaux, Melun, Senlis, Nangis, and coming close to Soissons, Gisors, Beauvais, Montereau on the Yonne, Nogent on the Seine, and Condé; but not being continuous within these limits, for it is frequently cut off in islands, and every where towards the outline deeply indented with bays. This vast basin consists of six different formations, in part calcareous, but in some of which gypsum is so plentiful, that the quarries dug in it go by the common name of the Plaster of Paris quarries, and indeed gypsum has derived it common name from these. The lowest bed upon the chalk is composed of plastic clay, and it has covered both the plains and the caves of the district. This bed is full of fossil remains, very many of them belonging to unknown animals, and it also contains fragments of rock, which have come from a great distance. Above this bed is a layer of gritty limestone and shelly grit, of salt-water formation. Then come in succession silicious limestone, fresh-water gypsum, and sand and grit without shells. The fourth formation is sandy, and of marine origin. The fifth has fresh-water remains and animals. The disposition of the land around and forming this basin wears in all respects the appearance of having been broken in upon and hollowed out by a prodigious irruption of water from the south-east. Considerable corrections have since been made, especially as regards the second and third of these formations of Cuvier.

It appears that the base or bottom of the Paris Basin must have been originally covered with the sea. Different parts of the ground were then covered with fresh-water lakes, from which gypsum and marl were deposited, filled with the bones of animals that lived on their banks or in their islands,

and died in the course of nature. After this deposition, the sea again occupied the ground, and deposited sand mixed with shells; and when it left the land dry for the last time, there were for a long while ponds and marshes over the greater part of the surface, which thus became covered with strata containing fresh-water shells, the base of those strata consisting of a peculiar stone found in fresh water, and occurring in many parts of France. The fossil remains in this great basin exhibit little variety of families; and the vegetable remains show that the plants were confined to palms and a few others now unknown in Europe. As the great continents, which offer a free communication throughout, are inhabited by a great variety of animals, while New Holland and the other islands in the South Seas have only a very few, and these almost all of the same family, we may conclude that the land forming the Paris Basin was originally surrounded by the sea.

The deposits in the rents or fissures of the strata may now be briefly mentioned, and they present a very singular subject of contemplation. They are found all around the Mediterranean, at Gibraltar, Cette, Antibes, Nice, Pisa; in Sicily, Sardinia, and Corsica; at the extremity of the kingdom of Naples; on the coast of Dalmatia; and in the island of Cerigo. The body of the deposit is calcareous, and of the same kind in all these gaps or fissures. The same, or nearly the same, bones are everywhere found imbedded in it; they are chiefly the bones of ruminating animals; and beside those of oxen and deer, there are found those of rodents, a kind of tortoise, and two carnivorous animals. In these fissures there are many land but no sea shells; and

the matter that fills them is unconnected with other strata. It follows from the first fact that they must have been consolidated before, and at the time when, the sea came over those countries and deposited shell-fish in the other strata ; and from the second fact it follows that they must have been formed when the rocks, in the rents of which they are found, were already formed and dry. Hence these fissure deposits are modern compared to the strata which were formed at the bottom of the sea and of lakes. Nor does any operation now going on upon our globe bear the least resemblance, in Cuvier's judgment, to that by which those deposits must have been made. Upon this, however, great controversy has arisen among his successors.

It was necessary that we should shortly advert to the places where, for the most part, these fossil remains are found ; in doing so we have anticipated a few of the conclusions deduced from the consideration of the whole subject. We are now to see what results were afforded by Cuvier's careful examination of the remains, which he instituted after he had with equal care ascertained the exact Osteology of the living animals in each case where the fossil remains appeared to offer a resemblance with existing tribes.

The *first* part of Cuvier's researches is occupied with the *pachydermatous** animals whose remains are found in alluvial deposits.

The *second* part consists of two subdivisions—in one of which are given minutely the whole details of the Paris Basin—in the other subdivision the examination of the animal remains, beginning with the pachydermatous, and then the others that accom

* Animals with thick skins, as the elephant, horse, hog.

pany them, whether quadrupeds, reptiles, fishes, or birds. So that the Paris Basin is made the ground of this arrangement, and its Fossil Zoology is gone through without much regard to the general arrangement of the rest of the work.

The *third* part is occupied with the *ruminant* animals, unless in so far as one of its subdivisions, treating of the gaps or fissures of the Mediterranean, also treats of the few other animals which are there found beside the ruminant.

The *fourth* part is occupied with *carnivorous* animals—the *fifth* with *rodents*—the *sixth* with *toothless* or *edentate* animals—the *seventh* with *marine mammalia*—the *eighth* and last, and perhaps the most interesting of the whole, with *reptiles;* including the anomalous species newly discovered, which partake of the nature at once of the reptile and fish or of the reptile and bird.

As no arrangement is yet made of these fossil animals under any of the heads which we have stated, we are at liberty to adopt any order that may appear most convenient; and we shall accordingly begin with those which at first appeared to resemble the known species of the rhinoceros, the hippopotamus, and the elephant, and which a careless observer would unquestionably have confounded with these animals; but they were soon ascertained to be different.

I. Of the fossil rhinoceros four distinct species have been found;* and they are all distinguishable from the four known kinds of rhinoceros—those of India, Java, Sumatra, and the Cape. The fossil animal had a head both larger and narrower than

* Of these there are now nine species, five having been discovered since Cuvier's work.

the living kinds, and much larger in proportion to his body. He was also much lower, and a more creeping animal. He, for the most part, had either no incisive teeth or very small ones, but one species had these of a good size. One of the fossil species is distinguished from all the four known ones and from the other three fossil ones, by a still more marked peculiarity; his nostrils are divided from each other not by a gristly or cartilaginous, but by a bony partition, whence the name of *Tichorhinus** has been given to him, the three others being termed *Leptorhinus*,† *Incisivus*, and *Minutus*.

The grinding teeth of the Tichorhinus are also found to have a peculiarity which no other teeth either of any living or any fossil animal have. They are indented at the base in one of the ridges, after being worn down by use. This, as well as the bony partition, affords, therefore, the means of discovering the species. The use of the partition apparently was to support the weight of two large and heavy horns on the nose.

The history of the first of these species, the Tichorhinus, furnishes a remarkable example of the errors into which even able and expert observers may fall when they make more haste than good speed to reach a conclusion. A missionary named Campbell having sent home the head of a rhinoceros, being one of several killed close by his residence, and well known to have been so, Sir Everard Home compared it with a fossil head from Siberia, sent by the Emperor of Russia to Sir Joseph Bankes; and finding, as he thought, that it was of the same species, he very rashly inferred that the position which affirms the existence of unknown

* From Τειχος, a wall. † From Λεπτος, slender.

animals among the fossil remains was much weakened by this supposed discovery. Cuvier made a more accurate comparison, and found that the Cape skull was materially different from the fossil one, but resembled the head of the existing species, which Sir Everard Home had also denied. The most remarkable omission, however, of the latter was his never looking to see if there existed a bony partition between the nostrils. This Cuvier did, and found it cartilaginous and not bony. So that the most singular of the new and unknown fossil animals belonging to this class remained still a novelty, even if Sir Everard Home had been correct in all the comparative examinations which he ever did make; and his conclusion of fact from that comparison, even if admitted to be well founded, had no bearing whatever upon the general position against which he had pointed it.

The extraordinary fact of a portion of one of these ancient and lost animals' muscular substance and skin having been found, is further to be mentioned. In a block of ice on the banks of the Wilujii, a river of Siberia, there was discovered this huge mass of flesh, about the year 1770. It was found to have longish hair upon parts on which the existing rhinoceros has only leather; consequently it must have lived in a colder climate than the present animal inhabits. But it appears to have been killed by some sudden catastrophe, and then to have been immediately frozen, else it would have undergone decomposition like the other remains of which the bones alone are left.

There are two species of living elephants, the African and the Asiatic; the former distinguished from the latter chiefly by the length of his tusks,

by a peculiar disposition of the enamel in the jaw teeth, and by never having been tamed, at least in modern times. The fossil elephant resembles the Asiatic species most, but differs in some material particulars. It has long tusks, sometimes exceeding nine feet in length; the jaw teeth are differently set; the under jaw of a different shape, as well as other bones; and from the length of the socket bones of the tusks the trunk must have been also very different. These remains* are found in great abundance both in Europe and in America, in neither of which parts of the globe are there now any living elephants of any species produced. In the same strata and caves other animals are also found both of the known and extinct classes; and occasionally shells also. The elephants' bones are chiefly discovered on plains of no considerable elevation and near the banks of rivers. They never could have been transported by the sea over the mountains of Tartary, upwards of 20,000 feet in height, which separate Siberia from the parts of Asia where the elephant now flourishes. It must be added, that, beside those bones, a still more perfect specimen of the softer parts has been preserved by the action of cold than we have of the rhinoceros. In the same country, near the mouth of the river Lena, a mass of ice was found in 1799 by a fisherman, which he could not break or move; but in the course of the next summer it partially melted, when it was found to contain an entire elephant frozen. The neighbouring Tartars with their dogs, and afterwards the bears, destroyed the greater part of the flesh, but the skin and bones were saved. It was found to

* There are now known eight species of this fossil elephant.

have hair, and even woolly hair or fur, upon different parts of the body. It must then have been calculated, like the animal of the Wilujii, for living in a climate much colder than that of India or Africa, and, like that rhinoceros, it must have been frozen immediately after its death. Its tusks were circular, and nine feet (near ten English) long.

Of the hippopotamus, two species* have been found among the fossil bones, both so different from all living animals, that every one bone of each differs from any other known bone; so that even if an error should have been committed in connecting the different bones together, there must be not only two, but more than two, new species thus discovered. These animals abound in the great deposit of fossil bones in Tuscany, in the valley of the Arno, and at Brentford in Middlesex. There are two other fossil species, of which, however, less is known; one of these is very small, not larger than a common hog.

Three pieces of a jaw-bone, with some fragments of teeth, have been found in Siberia; which upon examination prove to have belonged to a singular species, resembling both the rhinoceros and the horse, and forming probably the link between these two animals. The size is larger than the largest fossil rhinoceros. The discoverer, Mr. Fischer, has named it the *Elasmotherium*,† from the thin enamel plate which winds through the body of the tooth in a peculiar manner.

But much more is known of a lost species which approaches the elephant, although differing in some important respects both from the living and the

* Two more species have since been found.

† Ελασμος thin plate.

fossil elephant. The most remarkable difference in the Osteology is presented by the jaw teeth, which have the upper surface mamellated or studded with nipples; from whence Cuvier named it the *Mastodon.** When these tubercles are worn down by use, the surface of the tooth has a uniformly plane or uniformly concave surface. The structure of the vertebræ shows it to have been a weaker animal than the elephant; and the belly was considerably smaller. The lower part of the fore-leg was longer, and the upper joint shorter; the shoulder one-ninth shorter too. The pelvis was more depressed; the tibia and thigh bones materially thicker; and the body a good deal longer in proportion to the height. As it fed upon vegetables, and had a short neck and feet unfit for living in the water, it must have had a trunk; and it also had tusks. It seems to have fed upon the softer parts of vegetables, and to have inhabited marshy ground. Six species† have been discovered of this animal, chiefly differing from each other in the teeth; and of these six, two only are well known. The mastodon was long supposed to be peculiar to America, and was sometimes called the Ohio animal; but there have since been found teeth in different parts of Europe, evidently belonging to the two better known species; and the other four kinds are, to all appearance, European.

In the same strata with the remains of elephants, rhinoceroses, and other animals both of extinct genera and species, are almost everywhere found the bones and teeth of horses, very nearly resembling

* Or Mastodonte, which is sometimes, but unnecessarily, rendered by Mastodonton: μαστος, mamilla.

† Five more species have since been discovered.

those of the animal now so well and universally known. It yet happens that for want of due attention to a branch of anatomy more familiar to us than any except the human, naturalists have constantly fallen into error in examining fossil bones. Thus Lang, in his history of the figured stones of Switzerland, took a horse's tooth for a hippopotamus's; and Aldrovandinus in one work describes teeth of that class as giants', and in another as horses'; while several authors have confessed that they could not tell to what tribe such remains had belonged. Cuvier did not, therefore,-deem himself released from the duty of fully examining the common horse's osteology, merely because of the frequent and minute descriptions which had previously been given of it; and his intimate acquaintance thereby obtained with the nature of every bone and tooth, has enabled him to pronounce with confidence upon the existence of horses like our own among the unknown animals which inhabited the earth before the vast revolutions that changed both its surface and its inhabitants. He has, however, justly noted the fact that there is no distinguishing the bones of the horse, the ass, the mule, and the quagga: so that very possibly these remains may have belonged to any of those animals; and very possibly also to none of them, but to some fifth species, now, with the mastodon and other contemporary animals, extinct. The same remark is of course applicable to the bones of the hog and the wild boar, found occasionally among other fossil remains.

The tapir family in many important particulars resembles the rhinoceros; and those are often found in the same tertiary strata with the rhinoceros,

elephant, and mastodon, several species now wholly extinct, but allied to the tapir. Two of these must have been of prodigious size, the largest 18 feet (19¼ English) long and 11 (nearly 12 English) high.* But there are other species, to the number of twelve at least, whose size differs little from that of the tapir; the bones are somewhat different, however, and particularly the teeth, which, from the eminences or ridges upon them, Cuvier made the ground of the genus, to which he gave the name of *Lophiodon*.† It is in different parts of France that all these species were first found: the smaller ones always in strata of fresh-water shells, and in company with remains of either unknown land animals, or crocodiles and other river animals now found in hot climates; and in several places the strata in which they occur, have been covered over, after they had been deposited and their bed consolidated, with strata of an origin unquestionably marine. By far the greater part of fossil remains, both those which have been already described, and those which we are afterwards to consider, having been found in sandy, or calcareous, or other earthy strata. But some few are also found in imperfect coal or lignite. In the part of the Appenines where that range meets the Alps there is a tertiary coal stratum, and in it have been found two new genera of pachydermatous animals, and a third in the fresh-water deposit near Agen. Cuvier calls these *Anthracotheria*.‡

The general conclusion which is to be derived from the important branch of the inquiry of which

* This is now better known, and is called the *Dinotherium.*

† *Λοφιον*, a small hill, eminence, or ridge

‡ *Ανθραξ*, coal. Of these seven species are now known.

we have been analyzing the resulting propositions, is partly zoological and partly appertains to geology. The former portion of it is, that more than thirty kinds of land animals have left their fossil remains in the strata now forming dry land, but deposited under water; that of these, seventeen or eighteen* are now extinct, and have been wholly unknown since the earth was peopled with its present inhabitants, six or seven being of a genus now unknown, the others being new species of known genera; that twelve or thirteen kinds have, as far as their bones are concerned, the appearance of having belonged to the species which still inhabit the globe, although their identity is far from certain, depending only upon the similarity of their skeletons; and that animals of genera now almost confined to the torrid zone used formerly to inhabit high and middling latitudes. The geological portion of the conclusion is that some of these fossil remains have been buried by the last or one of the last revolutions to which our planet has been subjected, as they are in loose and superficial strata, whilst other remains in the tertiary strata appear generally to have come from deaths in the course of nature, though some of these too must have perished by a sudden revolution.

II. The Paris Basin presents, in great abundance, the remains of herbivorous pachydermatous animals of two distinct genera, each comprehending several species, and all alike unknown in the living world. The animals to which some of them approach the nearest are the tapirs; but they differ even generically from these, and from every other known tribe. The inquiry into which Cuvier entered for

* According as the Elasmotherium is allowed to be sufficiently distinguished or not.

the purpose of ascertaining to which set of bones each particular piece belonged, so that he might be able to restore the entire skeletons by putting together all the parts of each, was long, painful, and difficult in the highest degree. He had first to connect the two bones of the hinder feet together, in each instance, by minutely examining the relation of the pieces to one another; and this process could only be conducted by deriving light from the analogies of other and known animals. He then had the different bones of the fore feet in like manner to put together, in order to restore those fore feet. Next the hinder and fore feet of each animal were to be connected together. Afterwards he had to mount upwards and connect the bones of the body with the several feet. The teeth and head must next be referred to the limbs. Then the vertebræ and then the trunks were to be restored; and then other bones, not yet accounted for, were to have their places found. The result of this most elaborate and perplexing investigation, the details of which occupy the fifth part of a large quarto volume, and are illustrated by between sixty and seventy admirable plates, containing between six hundred and seven hundred figures of bones, fragments of bones, and congeries of bones, may be stated shortly thus:—There are of the first genus, which he denominates *Palæotherium*,* six, or perhaps seven, species† principally distinguished by the teeth and the size, as far as the bones are concerned, but which, probably, were much more widely different when alive. One of these resembled a tapir, but was only a foot and a half in length, being about

* Παλαιος, ancient; θηριον, wild beast.
† Eleven species are now known.

the size of a roebuck. Another was nearly three feet high, and the size of a hog. A third was between four and five feet in height, and about the size of the horse or the Java rhinoceros. It had feet thicker than a horse's, and a larger head; its eyes were very small, its head long, and it had a snout protruding much over its under jaw and lip. In a specimen of one of these species, the first now mentioned, there were actually found some of the animal's softer parts, certain flexible filaments, which, upon being burnt, gave an animal smell, and were manifestly portions of the nerves or blood-vessels. Besides these three species, three, and possibly four others, were distinguished, one the size of a hare.

The other genus was termed by Cuvier *Anoplotherium*,* and of these, two species, at least, are distinguishable.† The first, or *common* anoplotherium, is about the size of an ass, being four or five feet high, and its body four feet long, but with a tail of three feet long; it was probably an animal that lived partly in the water, as it appears made for swimming like an otter. But it has a peculiarity of structure which is to be found in no other animal whatever; its feet are cloven, but have two separate and distinct metacarpal and metatarsal bones, which are soldered together in other animals; it has also its teeth contiguous, while all other animals except man have them apart. The other species, or *secondary* anoplotherium, resembles the former, but is only the size of a common hog. But beside these anoplotheria properly so called, four other cognate species are found, one of the size and

*Ανοπλος, unarmed, without tusks.

† Six species are now ascertained.

appearance of a gazelle, one the size of a hare, and two of the size of a guinea pig. A curious specimen gives the very form of the anoplotherium's brain, a cast of it remaining in the earthy mass. Its size is extremely small, and Cuvier infers from this that the animal was exceedingly stupid.

All these animals are found in the Paris Basin; but bones of the palæotherium have been discovered elsewhere, namely, at Orleans, Aix in Provence, Montpelier, and Isell. As the specimens from those other places were extremely rare in Cuvier's time, he could not have the same certainty respecting them as from the more copious collections obtained in the Paris district. But he could distinguish at least three different species.

Beside these two new genera, the palæotherium and anoplotherium, the Paris Basin affords two other new genera of pachydermata, the one, called *Chæropotamus*,* resembling animals of the hog kind—the other, *adapis*, very small, being about a third larger than the hedgehog, which it also resembled in structure. There are found, too, the remains of five or six kinds of carnivorous animals;* one of them being of enormous size, and resembling a tiger. Another has projecting bones to support a bag or purse as in the kangaroo kind; but it is of a genus of marsupial animals now found only in America, being a sort of opossum. The Basin, besides, affords a considerable number of tortoise remains, some fish bones, and even perfectly complete skeletons of fish, and ten species, at least, of birds, all now unknown, but one of which resembles the Egyptian ibis. It is very remarkable that in one specimen, brought to Cuvier

* There are now three species known.

while his work was printing, the windpipe was preserved, and the mark or mould of the brain appeared upon the surface of the gypsum.

III. Of ruminating animals the fossil deposits present many remains. There are of the deer, beside divers that closely resemble known species, no less than twelve* species wholly unknown among the existing inhabitants of our earth. One has enormous horns, six feet from tip to tip, and of this animal we know nothing among existing species, though it comes nearest the elk. Two kinds are somewhat like roebucks, and of that size. The fissures of the Mediterranean give six new species,† of which that found at Nice is like an antelope or sheep.‡

None of our common oxen are found in a fossil state, unless in morasses or peat bogs, where they have certainly been buried while the globe's surface was in its present condition, and peopled as we now find it. But animals of the same genus certainly existed in the age of the elephant and rhinoceros, and of the extinct species.§ There prevails no small uncertainty as to the identity of the

* No less than twenty-eight species are now known.

† In the Résumé to Parts III. and IV., Cuvier says, "Of the six deer found in alluvial deposits, one with large horns is entirely unknown; of the four in fissures, three are unknown, at least in any but most distant countries. Another, that of Orleans, is quite unknown, as are the two species of lagomys found in the fissures."

‡ A thirteenth new species was at one time supposed to have been found in the Swedish province of Scania; but Cuvier, before the last volume of his work was printed, had reason to believe that this animal belonged to one of the tribes formerly known, and still living in the north of Europe.

§ Of these there are now seven ascertained.

fossil bison and musk buffalo with the living species of the former in Europe and of the latter in America; but the remains which have been found of a kind of ox, appear different from any known species, and it appears that no buffalo resembling either that of the East Indies or that of the Cape has been found in any place.

The conclusions, both zoological and geological, from this part of the investigation and from the examination of the remains found in the Paris Basin, in every respect tally with those to which we were led by a consideration of the pachydermatous remains under the first head of the inquiry.

IV. There are found in caverns both in France, Germany, Yorkshire, and Devonshire, and in the fresh-water formation of Val d'Arno, in Tuscany, the remains of many animals, some extinct and others no longer inhabitants of the same temperate latitudes, but confined to the frozen and the torrid zones. By far the greater part of these animals belong to the carnivorous class, except in the Yorkshire caves, where many of the herbivorous kind are also to be found. In the foreign caves the bear is the most numerous, and presents extinct species. In the Yorkshire caves (at Kirkdale) the hyæna predominates. In the German caves hyænas are comparatively few, and in Val d'Arno not more numerous. In Kirkdale there are very few bears. The race of lions and tigers is much more rare than any of the others. Not above fifteen have been found in Germany, while there have been found hundreds of bears; and in Yorkshire, where hyænas abound, very few lions and tigers are traceable. Of the wolf and fox, some are found, but not so many in Yorkshire. There is also a very large kind of

dog traced, which must have been five feet in height and eight in length from the mouth to the tail.

Of bears it appear, after a very close examination, that there are found, at least two species* larger than those now known, and a third which, both in size and other particulars, so nearly approaches the common bear, that Cuvier does not regard it as a new species. But it seems as if the one found in Tuscany formed a third kind of animal now extinct.

The hyæna† is found not only in the caverns and other quarries where the bear abounds, but also in the alluvial strata with the elephants and rhinoceroses. In Kirkdale cave his dung has been distinctly recognised by a comparison with that of living hyænas; and the particular crack which he makes in the bones of the beasts devoured by him to get at the marrow, has, in like manner, been identified by actual comparison. Nevertheless the fossil animal differs from the living one in some material respects, particularly in size, and in having his extremities both thicker and shorter. The caverns contain two species‡ of a huge animal of the felis (or cat) kind, considerably larger than the lion or the tiger, beside some few resembling living species in size. One is between one-eighth and one-ninth larger than the lion, and has its trunk more convex in the lower outline. A new, but smaller, species of the felis kind is also found in the Mediterranean fissures.

In the dog tribe there has been found a wolf or dog,§ but more probably the former, which differs,

* Seven more have since been added.

† Now eight species. ‡ Now fifteen.

§ Ten species are now known.

though slightly, from any known species, in having the muzzle shorter in proportion to the skull; and also a species has been observed clearly new of the same genus. We as yet only know of it by two of his jaw teeth, found at Avaray, near Beaugency. He must have been eight feet long and five high. The Paris Basin affords, likewise, another new species of the dog kind, but not materially varying in point of stature. The common fox, however, is found, and also the dog and wolf, in the caves.

The caves afford a considerable number of bones of the weasel and glutton,* closely resembling the existing species. The latter animal is only known now in the higher latitudes; but in the caves we find his remains mixed with those of animals belonging to the temperate and the torrid zones.

It is thus shown by the inquiries which comprise the third and fourth part of this great work, that the former inhabitants of these regions were wholly different from the present population. Even the animals of hot climates here found, and referable to existing genera, must have differed entirely from those species which survive in the torrid zone, because they could exist in a temperature now wholly foreign to their nature. The rein-deer and the lion, the sloth and the elephant, all found in the same places, show that the climate of those latitudes remains nearly the same, but that their inhabitants have been changed.

In all these researches one blank is immediately perceptible. There are not only no human remains whatever, but there are none of apes or of any of the genus of quadrumanes. Animals far less in size, and whose bones would much more easily have

* Of the fossil gulo two species are now ascertained.

perished, as rats and mice, have left their skeletons with those of the largest beasts; but of the monkey tribe no vestige whatever is to be discovered; and the conclusion is inevitable, that the strata were deposited, the fissures filled, the caverns strewed with bones, at an age anterior to the existence of that tribe, as well as to the creation of our own species. Thus it was when Cuvier wrote.*

V. Beside the animals of the *Rodent* description, found in the Paris Basin and the Mediterranean fissures, rabbits, lagomys, field mice, there are several others in the alluvial strata and caverns,—some apparently of known, and others, certainly, of unknown kinds. The hare has been traced at Kirkdale; the beaver near the Rhine; two new species† of the beaver near Rostoff, in the south of Russia; another species, also unknown, at Œningen.

VI. The toothless or *Edentate* animals afford some varieties still greater than those to which our attention has as yet been directed. None of the known species of this tribe are to be found in any of the strata, fissures, or caves in Europe. But three genera entirely new, with two of which at least there are ample materials for becoming acquainted, have been found in America, and these are deserving of our best attention.

The first is the animal named by Jefferson, from the size of his feet, or rather what he supposed claws, the *Megalonyx*,‡ and respecting which he

* This refers of course to the state of discovery in Cuvier's time. There are remains of the monkey said to have been lately discovered in the South of France and in the Himalaya Mountains; it is said also at Calcutta. But the proofs are not clear.

† Now four are known, and three of lagomys.

‡ Two species are now known.

fell into an error as we formerly stated. Cuvier preceded his examination of this as of all other animal remains by a thorough investigation of the osteology of living animals of this family; and it is the result of his careful enquiry that the bones found in America and described by Jefferson, and of which both casts and drawings were sent over, as well as a tooth, belonged to an animal of the sloth tribe, but wholly new, and now quite extinct. The tooth was cylindrical, and worn down on the top, but cased round with enamel like a sloth's, and not at all like a cat's. In the paw, the second phalangal bone was symmetrical. This bone is curved and not symmetrical in animals that raise up and draw back the claw, as all the cat kind do. The first phalangal bone, too, was the shortest; whereas the lion and others of the cat kind have that bone the longest. But from the known species of sloth it differs most strikingly in its stature, which was equal to that of the largest oxen, those of Hungary and Switzerland, and a sixth larger than the common kind.

The second of these new animals has been termed *Megatherium*, from his great size, and the remains are found in South America. From his teeth it appears that he lived on vegetables, but the structure of his very long fore paws and nails shows that it was chiefly on the roots. He possessed also good means of defence, and so was not swift of foot. His covering seems to have been a thick and bony coat of mail like the armadillo's. His length was twelve feet and a half (near thirteen feet and a half English), and his height seven feet (about seven feet and a half). From the sloth he differs not only in size but in other particulars; for example, his

fore legs are much nearer the length of his hinder legs than in the sloth, which has the former double the latter. But, on the other hand, the thickness of the thigh bone in the megatherium is much greater than in any of the known sloth tribe, or indeed any other animal either known or extinct; for the thigh bone is about half as thick as it is long.

The third of these new animals was known to Cuvier only by one fragment which he examined. It was a toe; and from a careful discussion of its form and size he inferred that the animal belonged to the edentate tribe of Pangolins, and that, if so, its length must have been twenty-four feet (twenty-six English), and its height in the same enormous proportion. The bones were found in the Palatinate near Eppelsheim.*

VII. The course of our analysis has now brought us to the family of the *Sea Mammalia*, and these supply new food for wonder. So different from the bones of any living animals are those remains which have been examined, that a new genus is formed consisting of several species, and bearing the same relation to the cetacea, or animals of the whale tribe, that the mastodon, palæotherium, and anoplotherium do to the pachydermata, or that the megalonyx and megatherium do to the edentata. He terms the genus *Ziphius*, from its having a sword-like head. One of these was found near the mouths of the Rhone. The dimensions are not given by Cuvier, but from the drawing the head appears to have been about three feet in length. The remains of a second species of ziphius were found thirty feet under

* Subsequent discoveries have made it probable that this toe belonged to the Dinotherium.

ground at Antwerp, and between nine and ten under the level of the sea at low water. The head is considerably larger than that of the first mentioned species. The head of a third species is found in the museum at Paris, but with no account of its history.

Besides this new genus, there are other cetacea of new species discovered among the fossil bones. At Angers a Lamantin of an extinct species has been traced. The remains of a dolphin, which must have been twelve or thirteen feet long, and different from all the known species, have been found in Lombardy. In the Landes another dolphin, which must have been nine or ten feet in length, has been discovered. A third kind of dolphin, different from any now living, has been found in the department of L'Orne, while a fourth, also found in the Landes, nearly if not wholly resembles the ordinary dolphin. In Provence a cetaceous animal of an unknown species is found, somewhat like the hyperodons.

In the neighbourhood of the Ochil hills in Scotland the fragments of a whale's bones have been found in a recent alluvial stratum, at only eighteen inches' depth, with a part of a deer's horn near. It must have been a whale of some size, as the vertebræ were eighteen inches broad, and one of the ribs ten feet long. But it is most probably one of a kind still existing in our seas, from the place where it was found.

In the mountains near Piacenza there have been found the bones of a small whale. Its length was twenty-one feet (near twenty-three of ours) and its head was six feet (near six feet and a half) long. The place where these bones lay was a clay stratum

with numberless shells all round, and oysters clinging to the bones. This animal was in a tertiary formation, six hundred feet above the plain of Italy. It appears to be of a new species.

In the very heart of the city of Paris have been found the bones of another whale, far larger, and of a species wholly unknown. Its head must have been fifteen or sixteen feet long, and its body fifty-four or fifty-five. It was found in a compact sandy bed in digging under the cellar of a wine-merchant.

The conclusion to which these Researches unavoidably lead is that the earth in its former state did not differ more widely in the races which inhabited it than the sea did—that ocean which was itself the great agent in producing many of the changes that have at various times swept away one race of living creatures from the surface of the globe, and mixed up their remains with those of animals engendered in its own bosom.

VIII. We have now reached the last and the most singular portion of these Researches; the examination of *Reptiles* whose relics are found in many of the stratified rocks of high antiquity.

In the calcareous schist, near Monheim, whence the stones used in lithography are gotten, a new species in the crocodile family is found, whose length must have been about three feet. At Boll, in Wirtemberg, another, apparently of the same kind, has been discovered. At Caen oolite quarries, a different and equally unknown species is traced; its body is between four and five feet long, and its whole length thirteen. Others of this family have been found in the Jura, and there they are accompanied by the fresh-water tortoise. At Honfleur

another species is found, and the remains of two other unknown kinds have been discovered near Harfleur and Havre.

Beside the remains of crocodile animals found in these more ancient strata, there are many also found in the more recent beds, where the bones of the palæotheria and lophiodons are deposited. The Paris Basin, the marl pits of Argenton, Brentford, and other places have furnished these specimens. But whether they were of different species from those new ones found at Monheim, Caen, and Honfleur, the examination which they had undergone in Cuvier's time was too imperfect to determine. They have since been shown to be different.

It deserves to be remarked of the new species of crocodiles, that their difference from the known kinds exceeds in manifest distinctness that of almost any other animals which are of the same genus, and do not differ in size; for the vertebræ, instead of being, as they are in the crocodiles now alive, concave in the front and convex behind, are convex in front and concave behind. This at once furnishes a very triumphant answer to those doubts which have been raised as to the novelty of the species, and still more signally discomfits the speculations of those who fancy that the difference perceived in fossil bones has been caused by change of temperature or of diet, or by the passing from the living to the petrified state.

The examination of fresh-water tortoises, of the genus trionix, whose remains are found in the plaster quarries and other strata, offers similar results. Thus at Aix in Provence a trionix of a new species is found. Another species, also new, is found in the Gironde; and two others have been

traced less distinctly in the gravel beds of Hautevigne (Lot et Garonne) and of Castelnaudary.*

Fossil fresh-water tortoises, of the genus emys, give the same results. They are found in the molasse of Switzerland, in the Sheppy clay near London, and in the limestone ridges of the Jura.

Fossil sea tortoises offer the like appearances. One of an unknown species is found near Maestricht, the genus being still living in the sea, and familiar to our observation. So that altogether the examination of tortoise remains leads to the same inferences of islands having existed in the ocean at a former period, inhabited chiefly by reptiles or oviparous quadrupeds, and before the creation of any considerable number of the viviparous orders.

As we proceed towards the close of these Researches the subject rises rather than falls off in curiosity and interest. We now come to the family of lizards, by which is here understood all the old genus of Lacerta (Lin.), excepting the crocodile and salamander tribes.

In the celebrated fossil fish deposits of Thuringia are found the remains of a monitor, of a species somewhat varying from the known species in two particulars, a greater elevation of the vertebral apophyses, and a longer leg in proportion to the thigh and foot. Remains of a similar aspect occur in France near Autun, and in Connecticut in North America.

In the strata of fine and granular chalk near Maestricht, between 400 and 500 feet in thickness, are found the remains of a huge reptile, which Mr. Faujas represented as a crocodile, following the opinions of the people in that neighbourhood; but

* Eight species have now been traced.

so celebrated an anatomist as Adrian Camper was not to be thus deceived, and he proved it to be an animal of a new genus, related to the monitor, and also to the iguana; it seems to be placed between the fishes on the one hand and the monitors and iguanas on the other. But the size constitutes its most remarkable difference when compared with these. They have heads five or six inches long; his was four or five feet, and his body fifty. He was therefore a lizard exceeding the size of a crocodile; just as the extinct tapir was the size of an elephant, and the megalonyx was a sloth the size of a rhinoceros. It appears that, like the crocodile, he was aquatic and could swim; and that his tail was used as a scull, moving laterally in the water, and not up and down like the cetacea, an order to which the elder Camper at first rashly referred him.

In the canton of Meulenthal, at Monheim, ten feet below the surface, and near some kinds of crocodile remains, bones were discovered of another unknown sub-genus of the order Saurus, and which Cuvier calls Geosaurus, and places between the crocodile and the monitor. It was apparently twelve or thirteen feet long, that of Maestricht being fifty.

A large animal of this family is found to have been an inhabitant of the same ancient world. At Stonesfield, in the neighbourhood of Oxford, Dr. Buckland discovered his remains in a bed of oolitic calcareous schistus under a solid rock of forty feet thick. The thigh bone is two feet eight inches in length, which would seem to indicate a body in the whole forty-five feet long. But even if his tail were not in the proportion of the lizard's, as this calculation assumes, his length must be, according to the cro-

codile's proportions, thirty feet. This animal approaches the geosaurus of Monheim, and also, in other respects, has some affinity with the crocodile and monitor; but in size he greatly exceeds the crocodile, and comes nearer the whale. His voracity must, from his teeth and jaws, have been extreme. He was also an amphibious animal; for his remains are surrounded with marine productions. The genus has been called *Megalo-saurus*. Teeth and bones of the same genus have been since discovered in Tilgate Forest, Sussex. Mr. Mantel has found in the same place the thigh bone of a much larger animal. Other reptiles have been found in the Muschelkalk quarries near Luneville.

But there are animals of the family of saurus yet more strange, if not for their size, at least for their anomalous structure and habits. A reptile is found of a genus so extraordinary as to comprehend within itself the distinguishing nature both of the lizard and the bird. It has a very long neck, and the beak of a bird. It has not, however, like a bird, wings without fingers to strengthen them; nor has it wings in which the thumb alone is free like a bat; but the wings spread by a single long finger, while the other fingers are short, and with nails like the fingers of ordinary apterous (or unwinged) animals. From these circumstances Cuvier has named this genus* the *Pterodactylus.*† It was first discovered by the late Mr. Collini, a Florentine, settled at Manheim, and formerly attached to the family of Voltaire, of whom he published some memoirs. The skeleton, nearly perfect, was found in the marly stone beds of

* There are now ten species observed.

† Πτερον, wing; δακτυλος, finger.

Aichstadt in the county of Pappenheim; but Mr. Collini fell into very great mistakes respecting the genus of the animal, which he supposed to be of marine origin, from not accurately investigating its osteology. The celebrated Sœmmering contended that it was one of the mammalia, resembling a bat, and other naturalists held the same opinion. But Cuvier has most satisfactorily shown, chiefly from its jaws and vertebræ, its shoulder-blade and sternum, that it is between a bird and a reptile, a flying reptile. The tail is extremely short, and this indicates the animal to have used its wings chiefly for locomotion: indeed, from its very long neck, it must have had great difficulty in either walking or crawling. When at rest, it must have stood like a bird on its hind legs, and also, like some birds, have bent back its long neck in order to support its very large and heavy head. Another species of the same genus, having a much shorter beak (for that of the former is longer than the whole body), has also been found near the same spot. It is much smaller. Very scanty remains of a third species also occur, found in the same quarries. Its size must have been nearly four times greater than that of the kind first mentioned, and it must have presented one of the most monstrous appearances which can be conceived, according to our present experience of animal nature.

The two last discoveries among the animals of a former world, which these researches have disclosed, remain to be mentioned; and they are, in the eyes of the naturalist, the most wonderful of the whole, although to an unlettered observer they may appear less strange than the tribe we have just been surveying. One of them has the muzzle

of a dolphin, the teeth of a crocodile, the head and breast of a lizard, the fins or paddles of a whale, but four instead of two, and the back or vertebræ of a fish. This has been named the *Ichthyosaurus*. The other, being apparently nearer to the lizard, has been called the *Plesiosaurus*;* and has also four paddles like those of a whale; the head of a lizard, and a long neck like that of a serpent. Both are found in the older secondary strata of the globe; in the limestone marl or greyish lias, filled with pyrites and ammonites, and in the oolite beds of the formation called Jurassic. They are both chiefly found in England, and were first discovered there.

Sir E. Home, in 1814, made the first step in the discovery of the Ichthyosaurus; having obtained some bones found on the Dorsetshire coast, thirty or forty feet above the level of the sea. He gradually obtained more of these remains, until 1819-20, when the discovery was completed. But he seems to have been unfixed and variable in his opinion respecting the animal; and after believing for some time that it was partly a fish, he ended by believing it to be no such thing, and changed its name from ichthyosaurus, which Mr. König had given it, as early as 1814, to *Proteosaurus*, supposing it to have some affinity with the proteus as well as the lizard.

The ichthyosaurus is most abundant in the lias strata in the lower region of the Jura formation. Its remains are not confined to Dorsetshire; they are found in Oxfordshire, Somersetshire, Warwickshire, and Yorkshire. But at Lyme they abound as much as those of the palæotherium do in the pits

* Πλησιος, near

of Montmartre at Paris. Some few specimens are found near Honfleur and at Altorf; in Wirtemberg, also, a nearly complete skeleton has been discovered. Four* distinct species were ascertained by Cuvier, chiefly differing from one another by their teeth, that is to say, as far as their osteology goes.† In the general features of their bones they all approximate to one another. The head resembles that of the lizard, although with material differences, and even having some other bones. The eyes are extremely large, differing in this from all the greater animals both sea and land. The cavity in some specimens is above a foot in diameter. Each eye is protected by a shield of bone, composed of several pieces knitted together. The vertebræ are very numerous. In some specimens as many as ninety-five are to be seen; and these differ entirely from the vertebral system of the lizard, resembling rather that of fishes, for they are flat like backgammon, and concave on both sides. The animal has four fins, or paddles, each composed of six rows of small bones, nearly one hundred in all, and so fitting into one another, that he could paddle about by means of them, moving with more elasticity than if the bones had formed a single

* Four species have since been added to these.

† It cannot be too steadily kept in mind that when a specific difference has once been ascertained, so as to distinguish one of these extinct races from another, the amount of that difference is no measure at all of the diversity which may have existed between the two animals. Tribes the most unlike have general resemblances in the bones, the substratum on which the muscular parts are placed. Witness the ease with which unlearned persons, nay, even naturalists carelessly observing, have taken the skeletons of lizards for those of men.

piece. The teeth are sharp. This creature could only breathe the air, and so must often have come up to the surface. Yet, again, he could only move in the water, and was still less able to crawl on land than even the sea-calf. The length, in some cases, reaches to twenty-four or twenty-five feet. In the strata where these bones are found there are many of the cornu ammonis and other marine shells, and remains of crocodiles exist in the same strata.

The plesiosaurus was first observed in 1821, by Mr. Conybeare and Mr. Delabeche; and in Cuvier's time its remains had only been found in England, unless those discovered at Honfleur belong to this genus. The discovery was fully made in 1824. The distinguishing feature, the long neck, has many more vertebræ than even a swan's. In the fine specimen from Lyme there are in all eighty-seven vertebræ, of which thirty-five belong to the neck and twenty-five to the tail. The vertebræ, though their axis is very short, resemble the crocodile's more than the lizard's. The teeth are pointed and slender. The paddles consist of many bones, in rows like those of the ichthyosaurus; but they taper more, consist of fewer pieces, not above fifty, and are longer than those of the ichthyosaurus, nor do they form a kind of pavement like his. Five species* of this animal were distinguished by Cuvier. That found at Lyme appears to have been seven or eight feet long; but other species, from one jaw bone which has been discovered, must have reached the length of twenty-eight feet.

* Three have since been added.

The eighth and last part of these Researches which we have just surveyed, is remarkable, as regards the skill and diligence of the illustrious author, for two particulars. *First*, the extraordinary success of his indefatigable investigation from very scanty materials derives especial attention. In some cases he had only one or two bones to examine and to reason from. In others he had a far greater number; sometimes he had the whole skeleton in scattered parts; in a few instances the whole together in their natural juxtaposition and connexion. But he found where he had many bones, that from a single one, or from two, he could have reached the very same conclusions which the examination of the whole led him to. This was observable in a very remarkable manner when he investigated the mosasaurus, or saurus found at Maestricht. He had not examined more than the jaw bone and the teeth when he knew the whole animal; but he says that a single tooth discovered it to him: he had got the key; after that every other part fell in at once of itself into its proper place. *Secondly;* Although he was not the discoverer of either the ichthyosaurus or plesiosaurus, and had to tread on ground which his eminent and able predecessors had gone over, his researches even here were quite original. He collected all the evidence, whether by drawings, descriptions, or models, of what had been before them; but he also enlarged his collection of facts by numberless specimens both of the same kind which they had examined and of different kinds never submitted to their view. He investigated the whole as if the field had been still untrodden and the soil yet virgin; and accordingly his work, even in this

subordinate branch, is far from being a repetition; his inquiries far from being a mere reiteration of theirs. Where he does not vary or extend the results at which they had arrived, he carefully confirms their propositions, and ascertains the truth of their learned conjectures; so that he adds to the precious monuments of his predecessors, by either enlarging the superstructure or strengthening the foundation.

That such a guide to our inquiries is worthy of all confidence, no one can doubt. That even his authority, the weight of his opinion, is very great would be a proposition as indisputably true, if in matters of science it were lawful for the learned to pay any deference to mere authority; yet even here ignorant men may bow to him, and receive his doctrine with a respect which they might be justified in withholding from others. But his system makes no such appeal, and requires not to be received upon terms like these. He has given us without any reserve every particular which his whole researches presented to his own view, and preferring the risk of being tediously minute to the chance of leaving any point unexplained, or any position without its needful proof, there is not a fragment of bone which he has ever examined, and on which he raises any portion of his philosophy, that he has not both described with the fulness of anatomical demonstration, and offered to the eye of his reader in the transcript of accurate and luminous engraving. His work is accompanied with between forty and fifty maps and sections of strata, above 250 plates representing upwards of 3800 skeletons, bones, teeth, and fragments. These are all presented to the examination of the

expert, in their connexion with the author's description both of what the diagrams can, and of what they cannot, fully represent. But they are also presented to the uninformed, who can, by attentively considering them, institute a comparison between the structure of known and living animals, and those of which the earth's strata contain only the remains. Giving Cuvier only credit for having correctly written down what he observed, and accurately represented in his figures the subjects of his examination, we are enabled to see the whole ground of his reasoning: we can mark the points in which a fossil animal resembles a living one, and those in which the two differ; and we have even a higher degree of evidence in behalf of the author's conclusions than we have in reading Sir Isaac Newton's experiments upon light, because every thing in this case depends upon configuration, which a drawing can accurately represent, whereas much in the optical case must needs turn upon appearances observed by the experimenter, and which no drawing can convey to our apprehension.

If again we compare the certainty and fulness of the proof in this case with that which we have in examining any anatomical proposition, or any doctrine of natural history, whether of animals or of plants, we shall still find it of a separate and higher kind. For in those branches of science much more is necessarily left to description. The question here is always one purely osteological as regards the animals; and osteology is of all branches of anatomy, whether human or comparative, the one where most depends upon mere figure, and where of consequence the reader can approach most nearly to the observer in weighing the proofs

on which his demonstration rests. The geological matter bears but a small proportion to the zoological in these inquiries. It is indeed of the highest importance; but it is incapable of much doubt, and admits of no mistake or imposition—for the strata where the different animal remains have been found are well known, and, in the very great majority of cases, are of easy access to all. The sciences of geology and mineralogy are sufficiently certain, at least for the main purposes of the inquiry; the names and description of the beds of the globe's surface are the portions of those sciences upon which no doubt or difficulty can exist; and the great body of Cuvier's results remains unaffected by any differences of opinion upon speculative geology.

Thus the comparison stands as to the degree in which the evidence is made plain to the reader of Cuvier's researches, and the reader of other records of discovery in the inductive sciences. But let us extend our view a little further, and compare the proofs before us in these volumes with those reasonings upon which the assent of mankind has been given, and is continued unhesitatingly, to the great truths of the mixed mathematical sciences. The reader of the "*Principia*," if he be a tolerably good mathematician,* can follow the whole chain of demonstration by which the universality of gravitation is deduced from the fact that it is a power acting in-

* It is the object of the Analytical View of that great work in this volume to make the demonstration, the proof on which the Newtonian system rests, so easy as to be followed by persons little skilled in mathematical science; but the remarks in the text will, it is to be feared, always remain well founded. The like may still more be said of the Analysis of La Place's Mécanique Céleste.

versely as the square of the distance to the centre of attraction. Satisfying himself of the laws which regulate the motion of bodies in trajectories around given centres, he can convince himself of the sublime truths unfolded in that immortal work, and must yield his assent to this position, that the moon is deflected from the tangent of her orbit round the earth by the same force by which the satellites of Jupiter are deflected from the tangent of theirs, the very same force which makes a stone unsupported fall to the ground. The reader of the "*Mécanique Celeste*," if he be a still more learned mathematician, and versed in the modern improvements of the calculus which Newton discovered, can follow the chain of demonstration by which the wonderful provision made for the stability of the universe is deduced from the fact that the direction of all the planetary motions is the same, the eccentricity of their orbits small, and the angle formed by the plane of their ecliptic acute. Satisfying himself of the laws which regulate the mutual actions of those bodies, he can convince himself of a truth yet more sublime than Newton's discovery though flowing from it, and must yield his assent to the marvellous position that all the irregularities occasioned in the system of the universe, by the mutual attraction of its members, are periodical, and subject to an eternal law which prevents them from ever exceeding a stated amount, and secures through all time the balanced structure of a universe composed of bodies, whose mighty bulk and prodigious swiftness of motion mock the utmost efforts of the human imagination. All these truths are to the skilful mathematician as thoroughly known, and their evidence is as clear as the simplest

proposition in arithmetic is to common understandings. But how few are there who thus know and comprehend them! Of all the millions that thoroughly believe those truths, certainly not a thousand individuals are capable of following even any considerable portion of the demonstrations upon which they rest, and probably not a hundred now living have ever gone through the whole steps of those demonstrations. How different is the case of the propositions discussed by Cuvier and his predecessors! How much more accessible are the proofs on which their doctrines repose! How vastly more easy is a thorough acquaintance with the "*Recherches*" than with the "*Principia*" and the "*Mécanique Céleste!*" How much more numerous are they who have as good reason for fully believing the propositions, because as great facility of thoroughly examining the proofs, as first rate mathematicians can have for assenting to Newton's third book, and La Place's great theorem, or as common readers have for admitting any of the most simple truths in the easiest of the sciences!

The extraordinary truths unfolded by the "*Recherches*" we have had an opportunity of stating in detail. But it is necessary to revert to some of the more general conclusions in their more immediate connexion with the great subject of these volumes. The Illustration derived to theological inquiry from the powers of inductive investigation in this branch of science, and the Analogy found between the two kinds of demonstration, was stated in the Introductory Discourse; but these form by no means the whole contribution which this new branch of knowledge furnishes to Natural Religion. Before the nature and extent of that aid could be

understood, it was necessary that the details of the science itself should be considered, and its general principles unfolded, together with the grounds upon which they rest. We are now more particularly to make the application.

To the geologist, as Cuvier has well observed, the vast periods of time over which the phenomena that form the subject matter of his inquiries have extended, offer the same kind of obstruction as the astronomer finds from the immense space over which his researches stretch. The distance of time is to the one as great a difficulty as that of space is to the other in prosecuting his researches. Yet as the properties of light, and its relation to media artificial or natural, furnish a help to the senses of the astronomer, so the endurable nature of the principal portions that compose the framework of animal bodies give invaluable assistance to the labours of the geologist and anatomist, supplying records which it is as physically impossible he should have in any history of past changes on the globe, as it is that the naked eye of the astronomical observer should penetrate into boundless space. The most minute bones of small animals, even their cartilaginous parts, and the most delicate shells of sea or river fishes, are found in perfect preservation. These shells are found, too, on ground now and for ages lying high above the level of any waters, in the middle of the hardest rocks, reaching the summits of lofty mountains, lying in vast layers of a regular form and solid consistency, and which seem to demonstrate the proposition that the sea in former ages was spread over the regions where those strata were formed, and lay there long and quietly. The level parts of the earth, which to an

observer who only regards its surface seems always to have been in its present state, can hardly be penetrated in any place without showing that it has undergone such revolutions and been under the sea for ages; while the bottom of the ocean has at those remote periods been dry land. But when we ascend to geater heights, we find the same proofs of former changes; marine remains often show themselves on Alpine summits, but their kinds vary much from those of the lower regions; they are exposed to view by the layers in which they lie imbedded being no longer horizontal and buried deep under ground, but nearly vertical, broken in pieces, and thrown variously about. These strata have for the most part been of a formation long prior to that of the horizontal ones, and were at one time displaced, and elevated and rolled about; the ocean was the great agent in their formation as in that of the strata which it afterwards deposited horizontally around them; the ocean, too, was the agent which, after having first deposited, afterwards dislocated and raised them into rocks, promontories, and islands, amidst which the strata still found horizontal were laid.

This ocean, at different times, not only held in solution different dead matter, but was inhabited by animals of kinds that exist no more. When it last left the earth and retreated into its present position, the only one in which we have ever known it by actual observation, its inhabitants nearly resembled those which still live and swarm in its waters. But at more remote periods, and when forming its more ancient deposits, it was the receptacle of animals of which not a living trace now remains; animals all whose species are extinct;

animals of genera absolutely different from any now known, and which sometimes united together in one individual frame, parts now only found separate in distant and unconnected tribes.

Again, the intermixture of land animals and of fish the inhabitants of fresh water only, with those of marine origin, shows that several successive irruptions of the ocean must have taken place, and that after it remained covering the land during successive periods, it retreated successively, and left that portion of the globe dry. Nor can there be any doubt that large portions of the earth now uncovered and inhabited by the human species and other tribes of living animals had, before it was last covered by the sea, been dry, and been inhabited by a race of animals of which their fossil remains are all that we can now trace.

It is probable, too, that many of these mighty revolutions have been sudden, and not effected by gradual incroachments upon the earth, to destroy its inhabitants. The examination of masses of flesh belonging to some of the race destroyed by the last change, and preserved by the frozen water in which they were imbedded, seems to prove that the death of the animals, and their envelopment in water, the coagulation of the water, and the introduction of a frozen climate, were simultaneous; for the putrefactive process had not commenced till thousands of years after the destruction of life, when, the ice being thawed, the exposure to heat and air began the decomposition. But the sudden violence by which these last changes were effected is equally conspicuous in the transport of huge blocks from one part of the country to another in which they were manifestly strangers.

But we ascend to greater heights on the surface of the globe, and we find the scene changed. We are now upon the vast and lofty chains of solid rock which traverse the central parts of the different continents, separate the rivers that water and drain them, veil their summits in the clouds, and are capped with never-melting snows. These are the primitive mountains; formed before any of the other new-made strata whereof we have already spoken, because they penetrate them vertically; and even these primeval rocks show by their crystallisation, and occasionally by their stratified forms, that they, too, were once in a liquid state, and deposited by waters which anciently held them in solution and covered the places they now fill. In these, as we ascend to the most ancient, no animal remains at all are found. The shells and other marine productions so abundant below, and in the more recent layers of the globe, here cease altogether to exist. The primeval rocks, therefore, were first held in a liquid state, and afterwards deposited, by an ocean which contained in its bosom no living thing; an ocean which before covered, or washed, a continent, or islands, on which life never had existed.

There is also little doubt, according to Cuvier, though we give not this as an incontestable proposition, that the prodigious changes which we have been contemplating must have been operated by a force wholly different from any that we now perceive in action upon any portion of the globe. The power employed to work some of the displacements of which we see the traces is shown remarkably in the insulated masses, found removed from great distances, and lying still at vast heights. On the

Jura, at near 4000 feet above the level of the sea, are found blocks of granite evidently carried from the Alps, one of which, containing 50,000 cubic feet of stone, has been removed and placed in its present position after the formation of the strata on or among which it lies,—strata, the materials of which do not fill its interstices, but have been rent and broken by its fall. None of the operations now observed on the earth's surface satisfactorily explain either this or the other revolutions in question. The effects of weather, either in the fall of rain, or in alternate freezing or thawing of water, though sufficiently powerful and very beneficial upon a small scale in decomposing stones and pulverising earths, are confined within comparatively narrow limits. The action of rivers in wearing down their banks, and changing the position of their beds, is restricted to those banks and beds, and is of slow and almost imperceptible operation, unless in some cases of rare occurrence, where a mountainous eminence being gradually undermined may fall and dam up a river and cause a lake to be formed, or where a lake may be let out of its reservoir by the wearing away of some ridge forming its dam or head, and so inundate the country below—events barely possible be it observed, and of which the period of authentic history records scarcely any instance. Then the incroachments of the sea are even more gradual than those of rivers; nor can any proof be found, in all the time over which authentic human annals reach, of a material change in position of the ocean with respect to its shores; the utmost it has ever done being to wear away an isthmus here and there,* or cover a mile or two of

* There seems reason, from some ancient authorities, to

low and flat coast.* The wonderful force of a column of compressed water, in a vertical fissure connected with a subterraneous sheet of it, however shallow, but filling a broad space—the resistless power of such a column to move about any superincumbent weight—has, perhaps, been too little taken into account as an agent in effecting changes on the earth's surface. But these operations must be all merely local. Volcanic action is still more topical in its sphere; and though violent enough within these narrow limits, produces consequences wholly confined to them, and unlike those which are under consideration. Lastly, whatever effect could be produced by the motion of the earth is of incomparably a more slow and gradual kind than any now enumerated. The motion of the poles round the plane of the ecliptic, and the nutation of the axis, are movements of this kind, and never exceeded certain narrow limits. The rotation of the earth has a regular and defined tendency to accumulate matter towards the equator, and flatten our globe at the two poles, but no other; and certainly neither a sudden nor a violent effect can be operated by this means.

The result of the Researches upon the fossil bones of land animals has demonstrated those changes still more incontestably than the examination of the remains which have been left by the

believe that the Isle of Wight was once a peninsula when the tide was out, to which tin, the staple of the ancient British exportation, was carried in waggons at low water to be shipped for Gaul.

* The estate of Earl Godwin in Kent, now covered by the sea, is one of the principal examples of this kind of change; and there must clearly be great exaggeration in the accounts given of it.

inhabitants of the ocean; both because, as they must have lived on dry land, their being found in strata deposited by water proves that water has covered parts of the continent formerly dry, and also because, their species being fewer in number and better known, we can now certainly tell whether or not the fossil animal is the same with any still living on the globe. Now of the one hundred and fifty quadrupeds examined by Cuvier, and whose remains are found deposited in different strata of our continent, more than ninety are at present wholly unknown in any part of the world; nearly sixty of these are of genera wholly unknown, the rest being new species of existing genera; only eleven or twelve are so like the present races as to leave no doubt of their identity, or rather of their osteology being the same; while the remaining fifty, though resembling in most respects the existing tribes, as far as the skeletons are concerned, may very possibly be found, on more close survey, and on examining more specimens, to differ materially even in their bones. Nor is it at all unlikely that, of the whole one hundred and fifty, every one would be found to be of a race now extinct, if we could see their softer parts as well as their bones and their teeth. But the relation which these different species of ancient animals bear to the different strata is still more remarkable and more instructive in every point of view.

In the *first* place, it appears that oviparous quadrupeds, as crocodiles and lizards, are found in earlier strata than those containing viviparous ones, as elephants and others. The earth which they inhabited must, therefore, have existed and been watered by rivers before the chalk formation, be-

cause they are found under the chalk in what is termed the Jurassic formation.—But, *secondly*, among the strata subsequent to the chalk formation, the unknown genera of animals, palæotheria, anoplotheria, are only found in the series of beds immediately over the chalk. A very few species of known genera of viviparous quadrupeds are found with them, and also some fresh-water fishes. —*Thirdly*. Certain extinct species of known genera, as elephants, rhinoceros, are not found with those more ancient animals of extinct genera. They are chiefly found in alluvial earth, and in the most recent tertiary strata, and all that we find with these extinct species are either unknown, or of more than doubtful identity with any now existing. Again, those remains which appear identical with the known species are found in recent alluvial earths, and places which seem to belong to the present world.—*Fourthly*. We have seen that the most ancient secondary strata contain reptiles and no other quadrupeds. None of the rocks at all contain any human remains; nor were any remains of the monkey tribe, or any of the family of quadrumanes found in Cuvier's time, if indeed they are observable even now. In turf-bogs, in rents and cavities, under ruins as well as in cemeteries, human skeletons are from time to time found; but not a vestige of them or of any human bone in any of the regular strata, or of the fissure deposits, or of the caves and caverns which abound with all the other animal remains. Whatever human bones have been found, were undoubtedly placed there by human agency in recent times.

For Cuvier has examined with the utmost care all the instances which were pretended to afford

proofs of human remains. He closely investigated several thousands of the bones in the Paris basin, and in the deposits of Provence, Nice, and others. All which had ever been supposed to be human he found to be either animal bones, or bones of men accidentally placed among the others, or in some other manner satisfactorily accounted for. The skeleton supposed by Scheutzer to be a man's, and which he made the subject of his book "*Homo Diluvii Testis*," a century ago, has been already adverted to. Cuvier undertook the complete examination of it. The first skeleton which formed the subject of Scheutzer's argument was found near Amiens. Thirty years afterwards another was discovered, but its possessor, Gesner himself, raised grave suspicions that it was some lower animal's remains. A more complete one than either was afterwards found. Cuvier has engraved this, together with Scheutzer's copied from his own book —and how any person could, upon the bare inspection, ever have conceived that either was a human skeleton is truly incomprehensible. But Cuvier has further engraved a land salamander, whose osteology he had, after his admirable manner, thoroughly examined, and its likeness to the fossil remains shows it to be of the same genus, though of a wholly new species, above six times larger. He enters at large into the details of the difference between these remains and the human skeleton. But a further demonstration of their nature was reserved for him when, in 1811, at Leyden, he had access to the actual fossil itself of Scheutzer, and was permitted to remove a portion of the incrusting stone. He did this with the salamander by him, and predicted the kind of bones that would be discovered

by the operation. The success of the experiment was complete; and to show the difference between this skeleton and a human subject, Cuvier had the satisfaction of also discovering a double row of small and sharp teeth, studding the fringe or border of the large circular mouth. In 1818, he had an opportunity of repeating this examination upon the last found specimen, which is now in the British Museum, and with exactly the same result. It is therefore demonstrated, as clearly as any fact in the whole compass of physical science, that these bones belong to a race wholly different from the human species, and indeed from any species now existing on the face of the globe. Finally, places where human bones have for many centuries been deposited with the remains of animals, as the ground under ancient fields of battle, have been examined, and it is found that the one are quite as well preserved as the other, and have not suffered more decay. The importance of establishing the conclusion that no human remains are to be found in the strata of the earth will presently appear, and is the reason why we have dwelt upon the evidence in some detail.

If we next inquire at what period the last great change took place, although of course no records can remain to fix it, yet we have some data on which to determine the limits of the question. The progress of attrition in the larger rivers, as the Dnieper and the Nile, and also the formation of downs where they approach from the sea, has been observed, as on the coast of the Atlantic in the south of France; and the results indicate no very remote antiquity as the age of the present terraqueous distribution; certainly not more than 5000 or 6000

years. Of these, history only goes back about 3000. Homer lived but 2800 years ago. Genesis cannot have been written earlier than 3300 years back. Even the earliest Chinese monuments that are authentic reach but 2255 years. The astronomical remains of the East, when closely examined, especially the Zodiac, prove nothing of that extreme antiquity which was at one time ascribed to them. Nor do the mines, such as those of Elba, from which similar inferences were formerly deduced, show, since their more accurate examination, anything of the kind. Indeed none of the conclusions they lead to can be regarded as at all of a certain kind. The general result of the Inquiry, then, is, that at a period not more remote than 5000 or 6000 years ago, a mighty convulsion covered with the ocean all those parts of the globe then inhabited by man and the other animals his contemporaries, and left dry those other portions of the earth which we now inhabit. The few remains of the races then destroyed have served to people this new world; it is only since this period began that we have entered upon the progressive state of improvement in which our race has advanced; and to this period whatever historical monuments we possess of the globe or its inhabitants are confined. But it is equally clear that this inhabited earth, then left dry for the last time, had previously undergone several revolutions, and had been alternately dry land and covered with the ocean, more than once, or even twice, before this last revolution. We have access more particularly to examine the condition and population of the earth when it was last inhabited, that is, when the sea left it the last time but one. We are now

living in the fourth era or succession of inhabitants upon this earth. The first was that of reptiles; the second that of palæotheria; the third of mammoths and megatheria; and it is only in this present or fourth æra in succession that we find our own species and the animals which have always been our companions.

We are entitled then to affirm that, with respect to animal life, three propositions are proved, all of great curiosity, and still more, when taken either separately or together, all leading to conclusions of the highest importance—

First—that there were no animals of any kind in the ocean which deposited the primary strata, nor any on the continent which that ocean had left dry upon its retreat;

Secondly—that the present race of animals did not exist in the earlier successive stages and revolutions through which the globe has passed;

Thirdly—that our own species did not exist in those earlier stages either.

Now the conclusion to which these propositions leads, and which indeed follows from any one of them taken singly, but still more remarkably from the whole, and most especially from the last, is that a creative power must have interposed to alter the order of things in those early times. That an interposition of this kind took place, the last and most important, about 6000 years ago, is highly probable from the physical and natural evidence alone which is before us, and to which alone in this work reference can be made. But the date is not material. If at an uncertain period before the present condition of the earth and of its inhabitants, there were neither men nor the present

race of creatures, wild and domestic, which people the globe, then it follows that between that period, whensoever it was, and the earliest to which the history of the world reaches back, an interposition of power took place to create those animals, and man among the rest. The atheistical argument, that the present state of things may have lasted for ever, is therefore now at an end. It can no longer be affirmed that all the living tribes have gone on from eternity continuing their species; and that while one generation of these passed away and another came up in endless and uninterrupted succession, the earth abided for ever. An interruption and a beginning of that succession has been proved. The earth has been shown not to have for ever abode in its present state; and its inhabitants are demonstrated, by the incontrovertible evidence of facts, to have at one time had no existence. Scepticism therefore can now only be allowed as to the time and manner of the creative interposition; and on these the facts shed no light whatever. But that an act of creation was performed at one precise time is demonstrated as clearly as any proposition in natural philosophy, and demonstrated by the same evidence, the induction of facts, upon which all the other branches of natural philosophy rest.

It is wholly in vain to argue that the sea or the earth, or the animals formerly existing and now extinct, or any other created beings, or any of the powers of nature, as we know it, or as it has ever been known, could have made the change. It is difficult enough to conceive how these known forces could ever have destroyed the earth's former inhabitants. But suppose the approach of some comet or other body at different times produced the vast

tides by which the land was successively swept, this will not account for new species and new genera of living creatures having sprung up both to inhabit the land and to people the waters. An act of creation—that which would now be admitted as a direct interposition of a superior intelligence and power—must have taken place. This is the sublime conclusion to which these Researches lead, conducted according to the most rigorous rules of inductive philosophy, precluding all possibility of cavil, accessible to every one who will give himself the trouble of examining the steps of the reasoning upon which they repose, and removing doubt from the mind in proportion as their apprehension removes ignorance. It is an invaluable addition to the science of Natural Theology, and forms a chapter as new in kind as any of the new animal species are in Natural History.

Such are the benefits conferred upon the great and fundamental argument of Divine Intelligence and contrivance by the recent discoveries in Fossil Osteology. The evidence of design in the combination and mutual adaptation of the parts of extinct animals we pass over as only a multiplication of proofs sufficiently numerous before. But the other branch of Natural Theology, that which investigates the Divine Benevolence, also derives aid from this new quarter. We now refer to the argument maintained in the Dissertation upon the Origin of Evil, and also to the theories which were there very respectfully considered, and diffidently and reluctantly found to be unsatisfactory. The late interesting discoveries have thrown new light upon both these subjects of discussion, and the authors of some of the systems which we examined may

appear to the improved state of our knowledge respecting the Chain of Being, as we certainly do make our appeal to it upon what appears to be a more solid ground of argumentation.

The doctrine respecting the Chain of Being is admitted to be incomplete as regards the matter of fact, inasmuch as we find many and large blanks in the series of animated creatures known upon our globe. Whatever other objections, therefore, were competent against this theory, an additional one was, that little appearance of a Chain of Being seems discernible in the universe. Now, the supporters of this doctrine have certainly a right to maintain that the blanks are filled up in a very remarkable manner by the recent discoveries. For the new species of animals discovered to have existed in former states of the globe, unquestionably fill up some of the most remarkable chasms in our series of living animals. Thus the chief blank was always observed in the pachydermatous animals, the fewest in number, the least approaching one another, and the whole tribe the most removed from others. Now most of the new and extinct kinds of quadrupeds belong to this class, and we have had occasion to observe how links are supplied between race and race hitherto appearing altogether distinct.

But although we may not be justified in reposing great confidence in the argument drawn from the plan of a Chain of Being as applied to the subject of positive evil, there is another point of view in which the subject may, with perfect safety, be considered. As far as regards mere defect, mere imperfection, it is most important to consider whether the plan of Divine Providence may not have been to create a succession of beings rising one above another in

attributes; say merely of intelligent beings thus differing in their approaches to perfection. The importance of this consideration cannot fail to strike the observer when he reflects that there is no possibility of separating one of the greatest of all positive evils, death itself, from mere defect or imperfection, as was observed in the Dissertation already referred to; not to mention many other kinds of evils arising from mere imperfection,—as all that proceed from weakness, from ignorance, from defect of mental energy, as well as mental perspicacity. All these evils, and all their various consequences, originate in mere defect or imperfection. Therefore it is of no little moment in this important argument that we should be able to derive any new light to guide our steps upon that part of the ground which belongs to defect or imperfection.

Now the late discoveries certainly afford us some such lights. They show as plainly as the evidence of facts can show anything, that there was a time when this globe existed with animals to people it, but without any beings at all of the human kind. The sounder opinion certainly is, that there has been a succession of stages through which the earth has passed, with different races of animals belonging to each period; that in the earliest age of all no animal life existed; that this was succeeded by another in which reptiles were found to flourish, and that subsequent periods were marked by other successive races of animated beings. But as this is the subject of controversy, we shall only say that there have been two eras, one in which inferior animals only existed without man, and the other in which we now live, and in which our species are the principal inhabitants of

the globe. This is admitted by all who have considered the evidence; and they who the most strenuously deny the other doctrines of Fossil Osteology avow their implicit belief in the great proposition, that the relics of an age are clearly discovered in which man had no existence.

Now this position is most important with a view to our present argument. It appears that there was a time when the Creator had not brought into existence any being above the rank of the lower animals. It follows that the divine wisdom had not then thought fit to create any animal endowed with the intelligence and capacity and other mental qualities of the human species. If an observer had been placed in that world, and been called upon to reason regarding it, what would have been his reflections on the imperfections of animated nature? Yet, after a lapse of some ages, those defects are all supplied, and a more accomplished animal is called into existence. The faculties of that animal, and his destinies, his endowments and his deficiencies, his enjoyments and his sufferings, are now the subjects of the observer's contemplation and of his reasoning. What ground has he now for affirming that a more perfect creature may not hereafter be brought into existence—a creature more highly endowed and suffering far less from the evils of imperfection under which our race now suffers so much? No one can tell but that as many of the former inhabitants of the globe are now extinct—tribes which existed before the human race was created—so this human race itself may hereafter be, like them, only known by its fossil remains; and other tribes found upon other continents, tribes as far excelling ours in power and in wisdom as we

excel the mastodon and the megatherium of the ancient world.

It is to be further observed that no uncreated being can, by the nature of the thing, have any right to complain of not being brought into existence earlier. The human race cannot complain of having come so late into the world; nor can any of the tribes created before us complain that they were less perfect than a species, the human, which did not then exist. Have *we*, then, the inhabitants of the present world, any better reason to complain that the new, as yet unknown, possible creatures of a future period of the universe have not as yet come into existence? It must be confessed that the extraordinary fact, now made clearly and indisputably* known to us, of a world having existed in which there were abundance of inferior creatures, and none of our own race, gives us every ground for believing it possible that Divine Providence may hereafter supply our place on the globe with another race of beings as far superior to ourselves as we are to them which have gone before us. But how inconceivably does this consideration strengthen and extend the supposition broached in the Dissertation upon Evil! How strikingly does it prescribe to us a wise and wholesome distrust of the conclusions towards which human impatience is so prone to rush in the darkness of human ignorance! How loudly does it call upon us to follow the old homely maxim, "When you are in the dark, and feel uncertain which way to move, stand still!" How forcibly does it teach us that much—

* The kind of controversy which may be raised, but never has been raised on this point, is discussed in the next dissertation.

nay, that all which now we see as in a glass darkly, and therefore in distorted form and of discoloured hue, may, when viewed in the broad and clear light of day, fall into full proportion and shine in harmonious tints!*

* Dr. Paley, in his twenty-fifth chapter, assumes, that whenever a new country has been discovered, with new plants and animals, these are always found in company with plants and animals which are already known, and possessing the same general qualities. From hence he derives an argument for the unity of the First Cause. Mr. Dugald Stewart also infers from the supposed identity of animal instincts in all ages, that the laws of physical nature must have always been the same, otherwise these animals could not have continued to exist.

Now, *first* as to Dr. Paley's assumption. It certainly appears too large, even as regards the existing species and the present state of the globe; for there seem to be some places where all the animals are peculiar. But be that as it may, the fact assumed is by no means necessary for the support of Dr. Paley's conclusion in favour of the Divine Unity. It is extremely probable that in some former stages of our globe there were no animals whatever of the same tribes with those which to us are familiarly known. Yet can there be any doubt that in their structure the same degree of skill is observable as far as their only remains enable us to judge, and can we hesitate to believe, that were there other parts before us, we should in those find as much artistlike contrivance as in the existing races of animals? Indeed we may go further and assert, that there is every ground for supposing that the same kind, as well as an equal measure of skill, is to be traced in the lost as in the existing tribes, and that, consequently, the characteristic argument will equally apply here. The proof of this in the structure of the alimentary canal, which Cuvier was not acquainted with, will presently be considered.

Secondly. With respect to the observation upon instinct, unquestionably some doubt may be raised by the new discoveries; for we cannot feel any confidence in the assertion that the animals, whose skeletons alone remain, were endowed with instincts similar to those now in being, more

especially the tribes of anomalous description, such as the pterodactylus and ichthyosaurus. We have never seen in life any animals combining the various forms which seem to have met in these extraordinary creatures. We cannot, therefore, feel entire confidence in the belief that their habits or instincts resembled those of any combination of animals so dissimilar,—still less can we comprehend a harmonious union of the instincts proper to birds with those peculiar to reptiles, which yet the pterodactyli seem formed to obey. Dark, however, as is this department of the subject, we have abundant ground, from the preponderating weight of analogy, for resting satisfied that all their instincts, whatever they may have been, were nicely adjusted to their bodily powers, and that both their bodies and their instincts were as nicely adapted to the laws of matter and of motion.

It would be improper not to mention at the close of this Analytical View, that the science of Palæontology was much indebted to some able and learned men who were contemporaries of Cuvier. The examination of the Paris Basin, as regards its mineral character, was almost wholly the work of Brongnart, and it is allowed to be a model in that kind. Cuvier's brother, also, ably assisted him in the botanical department. The labours of Lamarck in conchology are so universally known as to need no further mention; and among other names may be stated that of Miller of Bristol, as having made valuable contributions to these inquiries.

LABOURS OF CUVIER'S SUCCESSORS.

Many learned men were attracted by the discoveries of Cuvier, and devoted themselves to the cultivation of the same science. During the last twelve or fifteen years of his life they had joined in similar pursuits, and many of his opinions were modified, and many of his researches were materially aided, by their diligent and successful inquiries. As far as regards the general connexion between Organic Remains and Geology, indeed another inquirer had appeared in the field as early as himself, the laborious, modest, and sagacious William Smith, a civil engineer, who, unassisted and almost unknown, had been prosecuting his researches into the mineral state of England, and performed certainly the most extraordinary work that any single and private individual ever accomplished—the delineation of the strata of the whole country, in a set of underground maps, which he published in 1815, and followed afterwards with a work upon the relation between these strata and their Organic Remains. Although the results of his investigations were published thus late, he had many years before communicated the greater part of them freely to his private friends. It must be confessed that few men of greater merit, or more unassuming,

have ever adorned any walk of science, and few have ever made a more important step in assisting the progress of discovery.

The other able persons who have cultivated this branch of science are certainly endowed with greater learning, that is, book learning, than Mr. Smith could boast of, beside attending closely to actual observation in the field. Some of them, too, may fairly claim a high place as men of profound and original views. Where so many excel and prefer claims so undeniable to the gratitude of the world, it is invidious as well as difficult to make a selection, the rather as, happily, we still have the great benefit of their continued assistance. In Italy, Brocchi; in Switzerland, Studer, Hugi, Charpentier, and Agassiz, the able and zealous disciple to whom Cuvier gave up the department of fossil ichthyology, when composing his work on Comparative Anatomy; in Germany, Von Buch, Kaup, Count Münster, Goldfuss, Rosenmuller, Wagner, and the justly celebrated Humboldt; in Russia, Fischer; in Belgium, Burtin, Omalius, Dumont; in France, Beaumont, Brongnart, Blainville, Prevost, Boué, Brochant, Geoffroy; and in England, Conybeare, Mantell, Lyell as incident to his Geological Treatise, Clift, Delabeche, König, Hibbert, Broderip, Fitton, Bakewell, Greenough, Owen, Murchison, Professor Sedgewick, and Dr. Buckland. These, it is believed, are all, except Brocchi, fortunately still alive, and still actively engaged in the same interesting inquiries, though some of them rather confine their study to the geological portion of the subject. If from the brilliant assemblage the names of Sedgewick and Buckland were selected, but, as regarding Fossil Oste-

ology, the latter especially, private friendship could hardly be charged with officiously assuming to be the organ of the general voice—but, indeed, to record such merit might well seem presumptuous, where the panegyric is far less likely to reach after-times than the subject of its praise.

The labours of Cuvier's successors, as far as regards his doctrines, belong to one or other of three classes: to the progress which they have made in examining the fossil remains of former worlds, or conditions of our globe;* to the arguments which they have advanced in opposition to or in support of his theory respecting the relation that subsists between those animal remains and the strata in which they are found; and to the arguments adduced for or against his opinions respecting the formation and age of those strata. It may be proper to mention the things done under each of these heads, although the last is of comparatively little importance to the purpose of the present work, and the second is of considerably less moment, as regards Cuvier's proper subject, than the first.

I. Among the extinct mammalia of the pachydermatous order, we mentioned one which Cuvier referred to the tapir genus, but pronounced to have been of a gigantic size. He only had seen the jaw teeth of the animal. But since his time other important parts have been found, chiefly at Epplesheim, in Hesse Darmstadt: and a genus *Dinotherium* (having four species) has been established, of which this species is termed *giganteum*, his length having been apparently not less than eighteen or

* The notes to the Analysis of Cuvier contain statements of the numbers of new species discovered since his time.

nineteen feet. His distinguishing peculiarity is the having two enormous tusks, which are bent downwards like those of the walrus, but are placed at the front end of the lower jaw, so as to bend below the chin. Dr. Buckland has shown by most cogent arguments that he must have lived chiefly in the water, and these tusks in all probability were used in supporting him, anchored as it were, to the side of the river or lake while his huge body floated, as well as employed in digging for the roots upon which his teeth show that he fed.

Notwithstanding somewhat scanty materials, Cuvier had described and, as it were, restored the megatherium with extraordinary skill. But a further importation of bones from South America has enabled observers in this country to throw some additional light upon the structure and habits of this singular animal. These bones were found in the bed of the river Salados in Buenos Ayres, a succession of very dry seasons having brought the water unusually low. Mr. Clift, of the Surgeons' Museum, a most learned and skilful comparative anatomist, and pupil and assistant of John Hunter, examined them fully, and found many very singular particulars not before known respecting this animal. Among other things it appears to have a bony partition between its nostrils (septum narium) like the rhinoceros tichorhinus. The structure of its teeth indicates that they are formed by perpetual growth like the elephant's tusks, and not like his teeth by renewal. The enormous size of the tail never could have been conjectured from the analogy of the elephant and other pachydermatous animals. It was composed of vertebræ, of which the one at the root had a diameter of seven inches, and the diameter from

the extremities of the processes was no less than twenty-one inches. If then allowance be made for the muscle and integuments, it could not have been less than two feet in diameter at the root, and six feet in girth. There can be little doubt that it was used both as a weapon of defence and to support the animal in conjunction with part of his large feet, while the others were employed in digging or scraping away the earth in quest of his food. The fore feet were a yard long, and the bones of the fore legs were so constructed that the limb could have a lateral or rotatory horizontal movement for the purpose of shovelling away the soil. The bone of the heel is also of extraordinary length. The proportion of his bones to those of the elephant is very remarkable. The first caudal vertebra in the megatherium being twenty or twenty-one inches, in the elephant it is barely seven. The circumference of the thigh in the former is two feet two inches, in the latter one foot. The expanse of the os illii in the former no less than five feet one inch, in the latter three feet eight inches. The bony cover of the hide has also been now more fully examined. It was about an inch in thickness, and so hard as to resist all external violence. The cumbrous movements of this unwieldy creature exposing it to many kinds of danger, the hide served to defend it from some enemies, and the weight and strength of its limbs and tail enabled it to destroy others; escape from any by flight being quite impossible. Mr. Clift informs me that he has found in the region of the pelvis small lumps of adipocire. So that we have here an additional instance of the softer parts of an extinct animal still preserved in a state to which flesh is now often reduced by decomposition in water.

Mr. Darwin (grandson of the celebrated physician and poet) has found in South America many interesting remains. Among these are the bones of an edentate, between the megatherium and armadillo (largest kind); those of a huge rodent in size equal to the hippopotamus; and those of an ungulate quadruped the size of a camel, and forming the link between that class and the pachydermata.

In the lias stratum of Lyme Regis there was found in 1828, by Miss Anning (to whose skill in drawing, as well as her geological knowledge, Cuvier often acknowledges his obligations), a new species of pterodactylus with very long claws, and hence Dr. Buckland gave it the name of *Pter. Macronyx*. It appears to have been the size of a raven.

In 1824, Mr. Mantell discovered in the Tilgate sandstone, in Sussex, the remains of an herbivorous reptile allied to the iguana genus, but vastly larger; and he gave it the name of *Iguanodon.** Other parts of the animal have since been found in different places, as in Purbeck, and in the Isle of Wight. Mr. Murchison found a thigh bone three feet seven inches long; and in 1829, a metacarpal bone, of six inches long by five wide, was found in the iron sand, and a vertebra as large as an elephant's. The opinion of Cuvier referred the large thigh bone clearly to Mr. Mantell's reptile, whose dimensions must therefore have been enormous, though it was not carnivorous.

In 1834, a large proportion of the skeleton was

* This discovery had been made before the last edition of Cuvier's book, and is mentioned, though shortly, in the Analysis.

found in the Rag quarries near Maidstone. This confirmed all the previous conjectures as to the bones separately discovered. The length of this monstrous reptile is calculated to have been seventy feet from the snout to the tip of the tail, the tail to have been fifty-two feet long, and the body fourteen feet round.* Mr. Mantell also discovered in 1832, in Tilgate Forest, the remains of a lizard, which may have been twenty-five feet long, and was distinguished by a set of long, pointed, flat bones on its back, some rising from it as high as seventeen inches in length. He called it *Hylæosaurus*, from being found in the Weald.

There were found in 1836, a great collection of fossil bones in the département of Gers, in France, in a tertiary fresh-water formation. Above thirty species, all mammalia, were traced, and of these the greater part were new extinct animals, but all were of extinct kinds; two species of the dinotherium; five of the mastodon; a new animal allied to the rhinoceros, and another to the anthracotherium; a new edentate; and a new genus between the dog and racoon; but the most singular and new of the whole is the under jaw of an ape, which appears to have been thirty inches in height. But we must be very cautious in giving our assent to this, until we are better informed of the position where the jaw was found. It is certainly possible; but after the history of the Guadaloupe skeleton, clearly human, as clearly found among fossil remains, but now universally admitted to have been a recent deposit, we may pause before concluding that a deposit contrary to all other observations of

* Geol. Trans. N. S. vol. iii. pt. 2.

fossil bones should have occurred in any tertiary formation.*

In the time of Cuvier, at least before the completion of his great work, our knowledge was so scanty of the fossil osteology of the East, that we doubt if any allusion to it is ever made by him. Three most important contributions to this branch of science have since extended our knowledge in that direction, and a rich addition may soon be expected from Mr. Clift's labours upon a large recent arrival.

The first was by my excellent friend Mr. Craufurd, who, travelling in the Burman empire, was fortunate enough to discover a great number of fossil remains near the river Irawadi. These he generously gave to the Geological Society, and Mr. Clift proceeded to examine them with his wonted assiduity and skill. Among them were traced two new species of mastodon, in addition to the M. gigas, and M. angustidens, of Cuvier. One is termed by Mr. Clift *Latidens*, from the breadth of his jaw teeth; and the bones of his face exceed in size those of the largest Indian elephant. The other he calls *M. Elephantoides*, because his teeth approach much nearer the elephant's than those of Cuvier's species, or of the Latidens. This animal appears to have been smaller than the elephant. A hippopotamus smaller than the living animal, a rhinoceros, a tapir, and others, have also been

* I have lately seen an appearance of a stratum of calcareous matter, which a cursory observer would certainly have supposed to be a natural deposit in the ground; but its history was known from some rubbish through which lime had filtered, when part of Buckingham House was built, and there were bricks, tiles, &c., underneath it.

traced among these remains, as have a new lizard near the garial, and a crocodile near the common animal.*

The second of these discoveries was made on the north-east border of Bengal, at Carivari, near the Brahmaputra river. The remains were examined by Mr. Pentland. He traced a new species of anthracotherium, which he calls *Silicestre*, a new carnivorous animal of the weazel tribe, and a pachydermatous animal much smaller than any hitherto known, either living or fossil.†

The third and most remarkable of these collections is one discovered in the Markanda valley, and the Sivalik branch of the Himalaya mountains, in the year 1835. The curiosity of naturalists in India was immediately roused, and their industry directed towards the subject with that ardour which the relaxation of a sultry climate never abates, and that combined perseverance and ability which has ever marked the great men of our eastern settlements. Dr. Falconer and Captain Cautley have chiefly signalized themselves in this worthy pursuit; valuable aid has likewise been rendered by Lieut. Durand; and the result of their labours occupies one-half of the Asiatic Researches for 1836. They found first of all a new animal, of the ruminating class, whose skull is the size of a large elephant's, and which has two horns rising in a peculiar manner from between the orbits, with an orifice of great breadth and an extraordinary rising of the bones of the nose. They gave it the name of *Sivatherium*, from the place of its discovery, dedicated to the deity Siva. The breadth of the skull

* Geol. Trans. N. S. vol. ii. pt. 3. † Ib.

is twenty-two inches. Dr. Buckland has no doubt that it must have had a trunk, something intermediate between the elephant's and tapir's. They next found a hippopotamus of a new species, distinguished by having six incisive teeth, and a skull materially different from the other species, whether living or extinct. A new species of tiger was also discovered, which they called *Felis Cristata*, distinguished chiefly by the great height of the occipital bone. In the same place with these bones were found remains of the mastodon, and other known species of extinct animals; but the most interesting discovery was that of a camel, of which the skull and jaw were found. It is to be observed that no decisive proof of any of the Camelidæ, either camel, dromedary, or llama, had ever been hitherto found among fossil bones, although Cuvier had proved certain teeth brought from Siberia to be undoubtedly of this family, if they were really fossil, which he doubted. This discovery in India was therefore extremely interesting, as supplying a wanting genus. But for this very reason it became the more necessary to authenticate the position of this supposed camel's remains the more clearly, especially as there were abundance of existing camels in the country, which there could not be in Siberia. The Indian account is somewhat deficient in this respect, leaving us in doubt whether the bones admitted to bear a very close resemblance to the living species, were found in a stratum or loose and detached.*

* Asiatic Researches, vol. xix. pt. 1. Still more recently, it is said, a bone of the genus Simia has been found in the Sivalik Hills, and another in digging at Calcutta; but the particulars are unknown to me.

* Besides all these additions to our knowledge of species and genera, two remarkable observations or sets of observations have been first made by osteologists since the time of Cuvier. The one of these is the tracing of footsteps, the print of which has been left by animals upon the sand, or other material of the strata, while in a soft state. The other is Dr. Buckland's study of the intestines from their fossil contents, which he has called *coprolites.** The first of these curious inquiries is conducted by observing the impressions which the softer and more destructible parts of animals, whose very race has been extinct for ages, made upon the earthy strata of a former world; it is the object of the other inquiry to ascertain from the petrified fæces bearing the impress of the alimentary canal, the internal structure of extinct animals; and both subjects are certainly calculated powerfully to arrest our attention.

The footsteps, it appears, were first observed by my reverend and learned friend, Dr. Duncan (to whom the country is also so deeply indebted as the author of savings' banks), in Dumfriesshire. On examining a sandstone quarry, where the strata lay one over the other, or rather against the other, for they had a dip of forty-five degrees, he found these prints not on one but on many successive layers of the stone; so that they must have been made at distant periods from each other, but when the strata were forming at the bottom of the sea. No bones whatever have been found in those quarries. Similar impressions, though of smaller animals, have been observed in the Forest marble

* Κοπρος, fæces; λιθος, stone.

beds near Bath. The marks found in Dumfries-shire, of which there were as many as twenty-four on a single slab, formed as it were a regular track with six distinct repetitions of each foot, the fore and hind feet having left different impressions, and the marks of the claws being discernible. They appear to have been made by some animal of the tortoise kind.* But similar marks have since been found in other parts of the world. At Hessberg, in Saxony, they have been discovered in quarries of grey and red sandstone alternating; the marks are much larger than those in Scotland, and more distinct. In one the hind foot measures twelve inches in length, and the fore foot is always much smaller than the hind. From this circumstance, and from the distance between the two being only fourteen inches, it is conjectured that the animal was a marsupial, like the kangaroo. But one of the most remarkable circumstances observed is, that the upper stratum has convex marks answering to the concavity of the lower slab on which it rests, clearly showing that the former was deposited soft after the latter had been first printed by the foot in a soft state and then somewhat hardened. Dr. Kaup has termed the large unknown animal *Chirotherium*,† from the supposed resemblance of the four toes and turned-out thumb to a hand. In the summer of 1838 similar footsteps of the chirotherium, and of four or five small lizards and tortoises, with petrified vegetables of a reedy kind, have been observed in the new red stone at Storeton Hill quarry in Cheshire, near Liverpool. A discovery has within the last two years been made in the

* Edin. R. S. Trans. 1828. † Χειρ, hand.

state of Connecticut, near Northampton, where the footsteps of various birds, differing exceedingly in size, are found in inclined strata of sandstone, and evidently made before it assumed its present position. The marks are always in pairs, and the tracks cross each other like those of ducks on the margin of a muddy pond. One is the length of fifteen or sixteen inches, and a feathery spur or appendage appears to have been attached to the heel, eight or nine inches long, for the purpose of enlarging the foot's surface, and, like a snow-shoe, prevent the animal's weight from sinking it too deep. The distance between the steps is proportioned to their length, but in every case the pace appears to have been longer than that of the existing species of birds to which they approach nearest, the ostrich. Consequently, the animal must have been taller in proportion to his size. How much larger he was than the ostrich may be gathered from this, that the large African ostrich has only a foot of ten inches long, less than two-thirds of this bird, and yet stands nine feet high. These proportions would give a height of fourteen feet to the extinct animal. Some of the footsteps in the Storeton Hill quarry are eighteen inches in length. In the Forest marble of Bath the foot-marks of small marine animals are descried.

In examining the inside of the ichthyosaurus, the half-digested bones of the animals on which these ravenous creatures preyed are found in large masses. But there are also scattered in great abundance among their fossil remains the fæces which they voided; and these being in a petrified state have preserved the very form of the intestines in minute detail. The fæcal matter is generally dis-

posed in folds, wrapt round a central axis spirally. Some of these coprolites exhibit the appearance of contortion, and show that the intestines of the animal were spirally twisted; others, especially the smaller ones, give no such indications. The scales and bones of the prey are distinctly to be traced in the mass; these are the remains, undigested, of contemporary fishes and reptiles, including smaller ones of the beast's own tribe, on which he appears to have fed, as well as on other species. The light which these coprolites throw upon the structure of the animal's intestinal canal is sufficiently remarkable. The intestines are proved to have been formed like an Archimedes screw, so that the aliment in passing through was exposed within the smallest space to the largest surface of absorbent vessels, and thus drained of all its juices, as we find in the digestive process of living animals. The similar structure of the intestinal canal in the sharks and dogfish now existing has been noticed by naturalists; and Dr. Paley expressly refers to it as making compensation by its spiral passage for its being straight, and consequently short, compared with the intestinal passage in other animals. We also can distinctly trace in these coprolites the size and form of the folds of the mucous membrane that lined the intestines, and of the vessels which ran along its surface. As there is no part of the animal frame more easily destructible than the mucous membrane and its vessels, the preservation of its casts is certainly a peculiar felicity for the physiologist. Similar observations have, since Dr. Buckland's discovery, been made upon the coprolites of fossil fishes, in the Lyme Regis lias, in Sussex, in Staffordshire, and near Edinburgh. In

some places they take so fine a polish that lapidaries have used them for cutting into ornamental wares. One of the most singular coprolites was found by Lord Greenock (an assiduous and successful cultivator of natural science) between the laminæ of a block of coal near Edinburgh, and surrounded with the scales of a fish recognised by Professor Agassiz as of contemporary origin. To these observations a very curious addition has been made by the Professor, who found that the worm-like bodies described by Count Münster, in the lithographic slate of Solenhofen, are in fact the petrified intestines of fishes, and he has also found the same tortuous bodies occupying their ordinary position between the ribs in some fossil remains. He has named them *Coleolites*;* and certainly the representation given of them in the drawing resembles an actual intestine as accurately as if it were the portrait of it.

When Cuvier abandoned to Professor Agassiz the whole department of Fossil Ichthyology, he showed as happy and just a discernment of living character as he ever displayed in the arrangement and appropriation of animal remains. That admirable person has amply earned the honour thus bestowed on him by devoting his life to this extensive, obscure, and difficult study. The results of his laborious researches have been from time to time published in a great work upon fossil fishes; but as the arrangement followed as yet in the publication necessarily leaves the several parts incomplete, a distinct and satisfactory view of the whole cannot be formed until the work is finished. Some

* Κωλον, the great intestine.

of the discoveries, however, which bear upon the subject of our present inquiries may be shortly described. The importance of the study to fossil geology is manifest from this, that the class of fishes being continued through the successive periods of the different formations, while those of land animals are confined each within certain limits, and the fishes being also inhabitants of those waters in which all the aqueous deposits once were contained, we are enabled by Fossil Ichthyology, through various periods of the earth's formation, to pursue the comparison of a vertebrated animal's condition in each stage.

The Professor's classification is founded upon the form of the scales, which are adapted to the structure of each tribe, and afford a perfectly scientific principle of arrangement. He thus divides the whole into four orders:—the *Placoïdeans*,* whose scales are irregular enamel plates more frequently broad, but varying in dimensions down to a point or prickle; the *Ganoïdeans*,† with angular scales of bone or horn thickly enamelled and shining; the *Ctenoïdeans*,‡ with comb-like scales having a jagged edge and no enamel;§ the *Cycloïdeans*,|| whose scales are smooth at the edge, and composed of horn and bone, but unenamelled.¶

There were in all 8000 species of fish enumerated by Cuvier, of which more than three-fourths, or 6000, belong to the two last classes, and no one of either of these classes has ever been found in any formation anterior to the chalk; so that the whole of these 6000 kinds of fish have, to all appearance,

* Πλαξ, a tablet or plate. † Γανος, brilliancy.
‡ Κτεις, a comb. § Perch belong to this class.
|| Κυκλος, a circle. ¶ Salmon and herring are of this class.

been called into existence at a period long after the primitive, the transition, and all but the latest secondary formations. On the other hand, and in the earlier times of the secondary and transition strata, there existed species of the other two orders, which have comparatively few representatives surviving to our days. The Professor has thoroughly examined 800 fossil species of these two orders, and finds not a single exception to the rule thus laid down for the relation between different species of animals and successive formations of strata.* His deductions received further corroboration by the examination of 250 species, all of new and extinct fishes, submitted to him in England, and which were, for the most part, found in this country. The analogy in this respect between the results of Fossil Ichthyology and those of Cuvier's Researches is striking throughout. In the lower deposits of the lias there are found the remains of the great sauroïd fishes analogous to the fossil lizards of the same strata. More than two-thirds of the fishes found in the chalk strata are of genera now extinct. These extinct genera, however, of the newest secondary strata approach more nearly to the fishes of the tertiary strata than the fishes found in the oolite or Jurassic formation; insomuch that the Professor is disposed to range the chalk and greensand nearer to the tertiary than secondary formations on this account. Not a single genus even of those whose species are found in the Jurassic deposits is now known among existing fishes; nor is there a single species, and but few genera common to the chalk, and the older tertiary strata.

* Rapport sur les Poissons Fossiles, 1835, p. 38.

A third of those found in the strata of the later tertiary formation, as the London clay and the coarse limestone of the Paris Basin, are of extinct genera. The Norfolk crag and upper sub-appennine formation have, for the most part, genera found in the tropical seas; the tertiary formation generally approaches nearest to our living species, but the Professor affirms that, except one small fish, found in modern concretions on the coast of Greenland, not a single species exactly the same with those of our seas is to be found in a petrified state. This continued analogy is very important in a geological view.

In a zoological view it would be endless to attempt any analysis of the Professor's researches. Among the extinct species no less than 150 belonged to the family of sharks, whose services, in keeping down the increase, naturally so rapid, of fishes, have been required in all ages of the ocean. Different kinds of shark, however, appear to have belonged to different periods. Of the three sub-families into which the Professor divides the great class of sharks, the first is found in the earliest period of organic remains, the transition strata, and continues till the beginning of the tertiary, but there is now only one species of it existing, and that is found in New Holland. The second sub-family begins probably with the coal formations, and ceases when the chalk commences. The third begins with the chalk, and continues down through the tertiary formation to the present time. The form as well as the size of the extinct species differ in most things materially from the living, and in no respect do they vary more than in their covering or scales.

As the coprolites enable us to ascertain the inte-

rior structure of the extinct reptiles, so do they throw light upon that of fishes also, those especially of the sauroïd or lizard-like kind. We have even instances of their intestines being partially preserved by some fortunate accident. An example near Solenhofen has been mentioned already. A specimen was found in Sussex, where the stomach, with its different membranes, was retained. In a number of fishes found in the Isle of Sheppy the bony capsule of the eye was found entire; and in some other instances the plates forming the gills or branchiæ are perceivable.

It thus appears that great and important additions have been made to this interesting science since Cuvier, who may properly be termed its founder, ceased from his labours. But it would not be proper to pass from a consideration of the services rendered by his successors, without making mention of one illustrious inquirer, a man of truly original genius, who preceded him by a few years. John Hunter, whose unrivalled sagacity seemed destined to cast a strong light upon whatever walk of science he trod, had turned his attention, as early as 1793, to fossil bones, in consequence of a collection sent to this country by the Margrave of Anspach. He described and commented upon them in detail with his wonted acuteness; he adopted the same safe and natural course which Cuvier afterwards pursued with such signal success, of examining the known bones of existing species as well as those submitted to his consideration; and it appears, from some of his concluding remarks, that he perceived distinctly enough the specific difference of the fossil animals, at least of some among them. Thus, having compared the

fossil skull of a supposed bear with that of a white bear which he had procured from the owner of the animal while alive, he gives an accurate drawing of both, and marks their diversities, indicating his opinion that the fossil animal differed from all known carnivorous animals.* Who does not perceive that he was on the right track, and would have reaped a plentiful harvest of discovery, had he devoted himself to the general investigation of the subject?†

II. The speculations of succeeding zoologists or comparative physiologists have not only made no impression upon the anatomical results of Cuvier's inquiries, but they never appear to have been pointed towards that object. Considering the numberless instances in which he had to draw his conclusions or to form his conjectures from a very imperfect collection of facts, it is wonderful how constantly the fuller materials of his followers have confirmed his inferences. But geological inquirers have occasionally impugned his doctrines respecting the relation of the classes of animals to the successive formations of the strata that incrust our globe. It has been denied by some that any such relation at all can be truly said to exist. There seems, however, no possibility of maintaining this position, whether we agree wholly with Cuvier or not in the detail of his statements. For the fact is undeniable that some strata, let them have been arranged in

* Phil. Trans. 1794, p. 411.

† In the Hunterian Museum there is a large collection of fossil organic remains, selected with consummate skill, and showing the attention bestowed by this great man on the most delicate parts of organization which they exemplify.

whatever succession, formed and placed by whatever causes, contain the remains of certain classes of animals which are not to be found in other strata. It is another fact equally indisputable, that no animals now exist of the same kind with the greater part of those found in any of the strata. This appears to connect the different races of animals with the different strata. But it is said that this is not a chronological connexion, and affords no evidence of strata having been formed rather in one age than another. If it were so, there still would remain a foundation for the position which merely affirms a relation between organic remains and strata. But is it true? The principal reason assigned is, that although no animals of a certain kind are found in certain strata, supposing those strata to have been formed at a given period, the animals of the kind in question may have perished so as not to have been washed into the sea or other water in which the earthy matter was mixed, and from which it was deposited. Now, not to mention that this bare possibility becomes improbable in the degree in which the facts are multiplied and the observations of animals and strata extended, the researches respecting fossil fishes seem to negative the objection entirely. For if the different strata were made by the sea, and contain totally different remains of marine animals, it is clear that each must have been formed respectively in a sea inhabited by different animal tribes. The strict parallelism, too, which is observed between the connexion of different races of animals and that of fishes with different strata, lends the strongest confirmation to Cuvier's doctrines.

Ingenious and laborious attempts have been made

to show, that though many races of animals are now wholly extinct, the evidence fails to prove the non-existence of any race (except our own) at a preceding period; in other words, to disprove the proposition that many of the present races came for the first time into existence at a period subsequent to the time when we know that others existed, always excepting the human race, which it is admitted we have sufficient reason to believe did not exist in the earlier stages of the globe's formation. It cannot, however, be denied, *first*, that the extinction of many races of animals, which is admitted, affords a ground of itself for thinking it probable that new ones should be found to supply their places; *secondly*, that there seems nearly as little reason to regard the utter extinction of some classes as more improbable than the formation of others; *thirdly*, that the admitted creation of man destroys the whole support which the objection might derive from a supposed uniformity of natural causes, always acting, and removes the difficulty said to exist, of assuming different sets of principles to be in action at different periods of the world; *fourthly*, that the great number of facts which have been observed, all pointing uniformly in one direction, cannot be got over by suggesting mere possibilities for explanations. The improbability is extreme of one set of animals having existed at the same age with another set, when we find certain strata having the traces of the former without any of the latter, and *vice versâ*. This improbability increases in proportion to the number of the species. If these exceed hundreds, and even amount to many thousands, the improbability becomes so great as to reach what, in common language, we term a moral

impossibility. Now, there are 6000 kinds of fishes, of which not one specimen is to be found in any of the formations preceding the chalk. But suppose we lay out of view all question of one formation being older than another, there are certain strata in which none of those species are found. There is no disposition to deny that these strata were formed in the water; therefore, at whatever time they were suspended in the water, that water at that time contained none of those 6000 kinds which now people it. Then from whence did they all come if they existed at that period, and yet were not in the water when the strata were formed? But it is equally admitted that the water in those days contained many other kinds of fish now extinct, and found only in certain strata, and it contained some few which we find in other strata, and some which are still to be found in the sea. Can anything be more gratuitous than to suppose that all the fishes of a certain class were destroyed at the formation of those strata, while all those of another class were afterwards brought from a different part of the sea to succeed the last ones, and a certain small number survived to mix with other strata, or even to last till now?

The only sound objection that can be taken to the theory, is that to which the absolute assertion of the fact is liable. We can easily ascertain that certain species are no longer to be found living on the globe. But we may not be so well able to affirm with certainty that certain fossil genera of one formation may not hereafter be found in another, or, which is the same fact in another form, that certain living species may not be traced among fossil remains. Thus the small family of

the camel was wanting in all our fossil collections till the late discoveries in the Himalaya mountains have made it probable that a species of this class may be found to have existed there with the mastodon and other extinct mammalia. This is possible, perhaps likely. So an ape's jaw is supposed for the first time to have been found in a fossil bed in France with other races, and no quadrumane had ever been before traced in any part of the fossil world. The proof of this discovery is, however, as yet involved in some doubt, and even were it more precise, we should only have two instances in which the negative evidence had failed, leaving a multitude of others, hundreds of land and thousands of sea animals, of which no representatives are to be traced among the fossil remains of any country. It must always be recollected that the whole argument rests upon probability, more or less high. Even as regards the admitted non-existence of the human species, the mere evidence of osteological researches is not demonstrative; for although it is quite certain that among the thousands of animal remains which have been discovered and carefully examined, not a fragment of a human bone is to be found, it is barely possible that in some deposits as yet unexplored the skeleton of a man may be discovered. We have at present only to make our inference square with the facts; to affirm that, as far as our knowledge extends, there is no such relic of our race in the earlier strata of the globe; and to conclude that, considering the extent of past inquiries, the regularity of the connexion between other races of different kinds and various strata, and the portions of the earth over which our researches have been carried the

very strong presumption is against any such contradictory discovery being hereafter made.

III. Whatever opinion men may form upon the question raised by some antagonists of Cuvier's geological doctrines, all must allow that considerable light has been thrown upon the subject of discussion by their labours. Indeed a considerable addition to our knowledge has been made by some of these able and learned men, even admitting that they have failed to impugn the theory, and taking the facts which they have ascertained as forming an addition, by no means inconsistent with it. Thus the valuable work of Mr. Lyell has, in two essential respects, greatly advanced geological knowledge. He has examined, with a much more minute attention than had ever before been given to the subject, the action of the physical agents actually at work before our eyes, and has shown how extensively these may operate upon the structure of the earth's surface. It may be admitted, perhaps, that Cuvier had somewhat underrated their power, although the reader may still retain his opinion, that the force ascribed from the facts to those ordinary physical powers is inadequate to produce the effects which the phenomena present; that all the violent and sudden actions known on the globe are topical, being confined within comparatively narrow limits, and that the supposition of sudden and even instantaneous change on a vast scale in former periods has been too lightly taken up. Indeed, unless we suppose such changes as might happen from the disruption of a continent united by a small neck of land, like that which may be found once to have joined Gibraltar and Ceuta, it seems hard to imagine how a tract of country, extending from Hol-

land to beyond the Caspian, and from Scandinavia to the Carpathian mountains, could be drained of the sea, which certainly once covered it, or, having still more anciently been dry, could have been laid under water.*

But a much more important service has been rendered by Mr. Lyell's comparison between the different formations of the tertiary class; and although it is with unavoidable distrust of himself that any one little versed in geological science should venture to speak, it should seem that the division which he has thus succeeded in tracing of the tertiary period, may stand well with the previous system of Cuvier, and be received as a fact independent of the controverted matter with which it has been connected. With the important aid of several eminent conchologists, but especially of Mr. Deshayes, he examined the numbers of testaceous animals traced in different formations; and finding that in some strata the proportion of shells of living species was very different from others, he distributed the strata of this tertiary period into three classes accordingly; the earliest being those which contained the fewest of our living species. The latest of the three periods into which he thus subdivides the tertiary era he calls *pliocene*,† or more recent; the next before *miocene*,‡ or less recent; the earliest *eocene*,|| or dawning. Seventeen species of shells are common to the three divisions, of which

* In Mr. Whewell's learned work on the History of the Inductive Sciences, there are some acute and important remarks on the two theories, that of Uniform Action, and that of Catastrophes. B. xviii. c. 8.

† Πλειων, more, and Καινος, recent.

‡ Μειων, less. || Ηως, dawn.

thirteen still exist and four are extinct. In the pliocene the proportion of existing shells always exceeds one-third, and usually approaches one-half of the whole found. In the miocene, the existing shells fall considerably short of one-half, that is, the extinct species preponderate; indeed, of 1021 examined, less than a fifth were existing. There are 196 common to this and the last period, of which 82 are extinct. In the eocene period, the proportion of existing shells is much smaller, not exceeding three and a half per cent.; and there are only 42 common to this and the miocene. In the Paris Basin 1122 species have been found, of which only 38 are now known as living.

The theory of Cuvier and Brongnart respecting the successive formations in the Paris Basin, appears to require some modification in consequence of more recent examination. They considered that upon the chalk there was laid, first a fresh-water formation of clay, lignite, and sandstone; then a marine formation of coarse limestone; and then upon that a second fresh-water formation of silicious limestone, gypsum, and marl. The researches of Mr. Constant Prevost seem to show that instead of these three successive formations, there were laid on the chalk a clay formation of fresh-water origin, and then upon that, contemporaneously, three others, in different parts of the same Basin, namely, a fresh-water formation of silicious limestone. another of gypsum, and a marine formation of coarse limestone. In the rest of the series the two theories coincide.

It must, however, be observed that the more important doctrines of Fossil Osteology, even as regards their connexion with the history and structure

of the globe, do not necessarily depend upon the opinions which may be entertained of the more controverted points of geological theory, while the science of comparative anatomy exists alone, self-contained and independent of geology. But all must agree in admitting the important service which Osteology has rendered to geological inquiries, and in rejoicing at the influence which it has had upon those who pursue such speculations, in promoting a more careful study of facts, and recommending a wise postponement of theoretical reasoning, until the season arrives when a sufficient foundation for induction shall have been laid by the patient observer.

NOTES ON THE FOSSIL OSTEOLOGY.

NOTE I.

As some learned men are satisfied with the proofs of an ape's jaw-bone having been found at Sansan, in the south-west of France, and an astragalus of the same genus in the Sivalik hills, it is very possible that this genus may be added to those found in the strata of the Miocene period; for it is only in the more recent formations that these remains are supposed to exist. That they should be found in any of the Pliocene formations is in a high degree improbable; and even then we have only got to the middle of the Tertiary period. No one contends that in the earlier formations any such remains are to be traced.

But in case any objection should be raised to the argument in the text, upon the supposition that, because quadrumanous animals were supposed by Cuvier not to be traceable in any but the present portions of the globe's crust, therefore human remains may likewise hereafter be found in earlier formations, we may remark that, even if they were, contrary to every probability, there found, no one pretends to expect such remains in those strata where no mammalia of any kind have been discovered; and the argument in the text is wholly independent of the particular period at which the non-existence of our race is admitted. These considerations are fit to be borne in mind, since learned men, like Mr. Schmerling, are inclined to think that some human bones found in the same caves with the remains of hyænas and other

animals, are of contemporaneous origin. The great majority of geologists, however, refer the animals in question to the last geological era before the creation of man.

NOTE II.

The state of rapid and solid advancement in which the science of Palæontology now is, may make the summary of its doctrines in any one year little applicable to the next. The notes to the Analysis of Cuvier, and the subsequent account of the labours of his successors, may serve to show what inhabitants of the former surface of the earth are at present within our knowledge. But with respect to the two important classes of ichthyosaurus and plesiosaurus, the following abstract will prove convenient to the student who would compare the present state of our information upon these two fossil genera at present with what it was when Cuvier wrote. Nothing can better exhibit the rate, as it were, at which this science has been advancing. I am indebted to my learned, able, and excellent friend, Mr. Greenough, for this summary, which will be found to be marked with the accuracy, the clearness, and the conciseness which distinguish all his productions:—

ICHTHYOSAURUS.

1. Communis .... Cuvier, vol. ii. Lias—England and Wurtemberg.
2. Coniformis.... (See Journal of Acad. of Philadelphia.) Not known to Cuvier. Lias—Bath.
3. Grandipes..... (Geol. Proc., 1830.) Not known to Cuvier.
4. Intermedius... Lias—England and Wurtemberg.
5. Platyodon .... Lias—England and Wurtemberg.
6. Tenuirostris... Lias—England and Wurtemberg.
7. Ichthyosaurus . Kimmeridge clay.
8. Ichthyosaurus . Muschelkalk—Luneville and Mannsfield.

PLESIOSAURUS.

1. Goldfussii ..... Quarries of Solenhofen. Not known to Cuvier.

2. Carinatus ..... Lias—England and Boulogne.
3. Dolichodeirus.. Muschelkalk — Germany ; and lias—England.
4. Pentagonus.... Jura beds—France.
5. Profundus..... Variegated sandstone—Jura. Not known to Cuvier.
6. Recentior...... Kimmeridge clay.
7. Trigonus...... Calvados—north of France.
8. Trigonus...... Cuvier, vol. ii. p. 486. Lias, probably.

GENERAL NOTE RESPECTING EVIDENCES OF DESIGN.

All the inquiries in which we have been engaged lead to one conclusion of great importance. Notwithstanding the progress which has been made in various sciences, the things which have been discovered and ascertained bear an infinitely small proportion to those of which we are still either wholly ignorant, or imperfectly and dubiously informed. In a vast variety of instances, design and intelligence have been traced—instances so well deserving to be called innumerable, that we are entitled to believe in contrivance as the universally prevailing rule, and we never hesitate so to conclude. But the mode and manner of the working is still, in a prodigious number of cases, concealed from us; and we are entitled to infer that numberless things which now seem irregular, that is arranged according to no fixed rule, are nevertheless really disposed in an order which we have not discovered, which would, if we knew all, be as complete as that observed and traced in the cases known to us. Thus the regular working of bees, which we have been examining, is reducible to certain known rules; the figures formed by them are, in all their relations, familiar

to mathematicians. The problems of maxima and minima, on the solution of which those operations proceed, may have parallels in the case of other animals; it is not at all improbable that the beaver forms his dike for protection against the water upon some such principle, namely, of the form which is better than any other conceivable form calculated to oppose a solid resistance to the pressure of water.* It appears probable that the works of spiders in concentric circles, and along their radii, are also regularly arranged in known figures, and upon similar principles. Many of the parts of plants wear the semblance of regular and symmetrical curve lines, insomuch that a mathematician once presented a paper to the Royal Society (on some propositions in the higher geometry), which he entitled, from the form of the lines investigated, "*Fasciculus Florum Geometricorum.*" The orbits in which the heavenly bodies move, come manifestly within the same remark still more certainly; for the forms of those paths, the relation of all their points to given straight lines, is in a great degree ascertained. But it seems very reasonable to conclude, that the small number of such regular figures which the state of science in its various branches has as yet enabled us to trace, is as nothing compared with those figures still so unknown to us, that in common speech we talk of them as irregular, while this is only a word, like chance, implying our own ignorance.

For the mathematical sciences, extraordinary as the progress already made may be reckoned, with regard to the difficulty of the subject, and the imperfect faculties

* The base of the dike being 12, the top 3 feet thick, and the height 6 feet, the face is the side of a right angled triangle, whose height is 8 feet; and if the materials were lighter than water in the proportion of 44 : 100, this construction would be the best one conceivable to prevent the dam from turning round. But the form flatter than that which would best serve this purpose when the materials are heavier than water, is probably taken to prevent the dam from being shoved forward.

of man, are most probably still in their infancy. Of the infinite variety of curve lines, we know but a very few with any particularity, to say nothing of our equal ignorance (connected with the former) of most of the laws of complex motion. In the parts of animal and vegetable bodies, especially of the larger kind, there are few symmetrical forms observed; greater convenience, in the former instance at least, is evidently attained by other shapes. Yet there seems no reason to doubt that all the forms which we see may be in reality perfectly regular, that is, that each outline is a curve, or portion of a curve, related to some axis, so that each of its parts shall bear the same relation to lines similarly drawn from it to this axis, which all its other points do. If we know little of algebraical curves, we know still less of those whose structure is not expressible by the relations of straight lines and numbers, the class called mechanical or transcendental, the forms of some of which are very extraordinary, but all whose points are related together by the same law. There is every reason to expect that the further progress of science will unfold to us much more of the principles upon which the forms of matter, both organic and inorganic, are disposed, so that the order pervading the system may be far more clearly perceived.

So of motion—In one most important branch, dynamics is still in its infancy; we know little or nothing of the minute motions by which the particles of matter are arranged, when bodies act chemically on each other. Even respecting the motions of fluids so much studied as electricity, and heat (if it be a fluid), and the operation of the magnetic influence, science is so imperfect, and our data from observation so scanty, that mathematical reasoning has as yet hardly ever been applied to the subject. It is the hope of men who reflect on these things, and it is probably the expectation of those who most deeply meditate upon them, that, in future times, a retrospect upon the fabric of our present knowledge, shall be the source of wonder and compassion—wonder at the advances made from such small beginnings—compas-

sion for the narrow sphere within which our knowledge is confined :—and when the greater part of what we are now only able to believe regular and systematic from analogy and conjecture, will have fallen into an order and an arrangement certainly known and distinctly perceived.

ANIMAL MECHANICS,

OR,

PROOFS OF DESIGN IN THE ANIMAL FRAME.

BY

SIR CHARLES BELL, K.G.H., F.R.S.

ANIMAL MECHANICS.

CONTENTS.

PART I.

THE PERFECTION OF DESIGN IN THE BONES OF THE HEAD, SPINE, AND CHEST, SHOWN BY COMPARISON WITH ARCHITECTURAL AND MECHANICAL CONTRIVANCES.

PART II.

SHOWING THE APPLICATION OF THE LIVING FORCES.

ILLUSTRATIVE WOODCUTS.

PART I.

THE PERFECTION OF DESIGN IN THE BONES OF THE HEAD SPINE, AND CHEST, SHOWN BY COMPARISON WITH ARCHITECTURAL AND MECHANICAL CONTRIVANCES.

INTRODUCTION.

To prepare us for perceiving design in the various internal structures of an animal body, we must first of all know that perfect security against accidents is not consistent with the scheme of nature. A liability to pain and injury only proves how entirely the human body is formed with reference to the mind; since, without the continued call to exertion, which danger and the uncertainty of life infer, the development of our faculties would be imperfect, and the mind would remain, as it were, uneducated.

The contrivances (as we should say of things of art) for protecting the vital organs are not absolute securities against accidents; but they afford protection in that exact measure or degree calculated to resist the shocks and pressure to which we are exposed in the common circumstances of life. A man can walk, run, leap, and swim, because the texture of his frame, the strength and power of his limbs, and the specific gravity of his body, are in relation with all around him. But, were the atmosphere lighter, the earth larger, or its attraction more—were he, in short, an inhabitant of another planet, there would be no correspondence between the strength, gravity, and muscular power of his body, and the elements around him, and the balance in the chances of life would be destroyed.

Without such considerations the reader would fall into

the mistake, that weakness and liability to fracture imply imperfection in the frame of the body, whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident, and to become, in the course of life, more and more fragile, until, by some failure in the frame-work or vital actions, life terminates.

And this leads us to reflect on the best means of informing ourselves of the intention or design shown in this fabric. Can there be any better mode of raising our admiration than by comparing it with things of human invention? It must be allowed that we shall not find a perfect analogy. If we compare it with the forms of architecture—the house or the bridge are not built for motion, but for solidity and firmness, on the principle of gravitation. The ship rests in equilibrium prepared for passive motion, and the contrivances of the ship-builders are for resisting an external force : whilst in the animal body we perceive securities against the gravitation of the parts, provisions to withstand shocks and injuries from without, at the same time that the frame-work is also calculated to sustain an internal impulse from the muscular force which moves the bones as levers, or, like a hydraulic engine, propels the fluids through the body.

As in things artificially contrived, lightness and motion are balanced against solidity and weight, it is the same in the animal body. A house is built on a foundation immoveable, and the slightest shift of the ground, followed by the ruin of the house, brings no discredit on the builder; for he proceeds on the certainty of strength from gravitation on a fixed foundation. But a ship is built with reference to motion, to receive an impulse from the wind, and to move through the water. In comparison with the fabric founded on the fixed and solid ground, it becomes subjected to new influences, and in proportion as it is fitted to move rapidly in a light breeze, it is exposed to founder in the storm. A log of wood, or a Dutch dogger almost as solid as a

log, is comparatively safe in the trough of the sea during a storm—when a bark, slightly built and fitted for lighter breezes, would be shaken to pieces: that is to say, the masts and rigging of a ship (the provisions for its motion) may become the source of weakness, and, perhaps, of destruction; and safety is thus voluntarily sacrificed in part, to obtain another property of motion.

So in the animal body: sometimes we see the safety of parts provided for by strength calculated for inert resistance; but when made for motion, when light and easily influenced, they become proportionally weak and exposed, unless some other principle be admitted, and a different kind of security substituted for that of weight and solidity: still a certain insecurity arises from this delicacy of structure.

We shall afterwards have occasion to show that there is always a balance between the power of exertion and the capability of resistance in the living body. A horse or a deer receives a shock in alighting from a leap; but still the inert power of resisting that shock bears a relation to the muscular power with which they spring. And so it is in a man: the elasticity of his limbs is always accommodated to his activity; but it is obvious, that in a fall, the shock, which the lower extremities are calculated to resist, may come on the upper extremity, which, from being adapted for extensive and rapid motion, is incapable of sustaining the impulse, and the bones are broken or displaced.

The analogy between the structure of the human body and the works of human contrivance, which we have to bring in illustration of the designs of nature, is, therefore, not perfect: since sometimes the material is different, sometimes the end to be attained is not precisely the same; and, above all, in the animal body a double object is often secured by the structure or framework, which cannot be accomplished by mere human ingenuity, and of which, therefore, we can offer no illustration strictly correct.

However ingenious our contrivances may be, they are not only limited, but they present a sameness which be-

comes tiresome. Nature, on the contrary, gives us the same objects of interest, or images of beauty, with such variety, that they lose nothing of their influence and their attraction by repetition.

If the reader has an imperfect notion of design and providence, from a too careless survey of external nature, and the consequent languor of his reflections, we hope that the mere novelty of the instances we are about to place before him may carry conviction to his mind; for we are to draw from nature still, but in a field which has been left strangely neglected, though the nearest to us of all, and of all the most fruitful.

Men proceed in a slow course of advancement in architectural, or mechanical, or optical sciences; and when an improvement is made, it is found that there are all along examples of it in the animal body, which ought to have been marked before, and which might have suggested to us the improvement. It is surprising that this view of the subject has seldom, if ever, been taken seriously, and never pursued. Is the human body formed by an all-perfect Architect, or is it not? And, if the question be answered in the affirmative, does it not approach to something like infatuation, that possessing such perfect models as we have in the anatomy of the body, we yet have been so prone to neglect them?

We undertake to prove, that the foundation of the Eddystone lighthouse, the perfection of human architecture and ingenuity, is not formed on principles so correct as those which have directed the arrangement of the bones of the foot; That the most perfect pillar or kingpost is not adjusted with the accuracy of the hollow bones which support our weight; That the insertion of a ship's mast into the hull is a clumsy contrivance compared with the connexions of the human spine and pelvis; And that the tendons are composed in a manner superior to the last patent cables of Huddart, or the yet more recently improved chain-cables of Bloxam.

Let us assume that the head is the noblest part; and let us examine the carpentry and architectural contrivances exhibited there.

But, before we give ourselves up to the interest of this subject, it will gratify us to express our conviction, that the perfection of the plan of animal bodies, the demonstration of contrivance and adaptation, but more than these, the proof of the continual operation of the power which originally created the system, are evinced in the property of life,—in the adjustment of the various sensibilities,—in the fine order of the moving parts of the body,—in the circulation of living blood,—in the continual death of particles, and their removal from the frame,—in the permanence of the individual whilst every material particle of his frame is a thousand times* changed in the progress of his life. But this is altogether a distinct inquiry, and we are deterred from touching upon it, not more from knowing that our readers are not initiated into it, than from the depth and very great difficulty of the subject.

* The old philosophers gave out that the human body was seven times changed during the natural life. Modern discoveries have shown that the hardest material of the frame is changing continually; that is, every instant of time, from birth to death.

CHAPTER I.

ARCHITECTURE OF THE SKULL.

It requires no disquisition to prove that the brain is the most essential organ of the animal system, and being so, we may presume that it must be especially protected. We are now to inquire how this main object is attained?

We must first understand that the brain may be hurt, not only by sharp bodies touching and entering it, but by a blow upon the head, which shall vibrate through it, without the instrument piercing the skull. Indeed, a blow upon a man's head, by a body which shall cause a vibration through the substance of the brain, may more effectually deprive him of sense and motion than if an axe or a sword penetrated into the substance of the brain itself.

Supposing that a man's ingenuity were to be exercised in contriving a protection to the brain, he must perceive that if the case were soft, it would be too easily pierced; that if it were of a glassy nature, it would be chipped and cracked; that if it were of a substance like metal, it would ring and vibrate, and communicate the concussion to the brain.

Further thoughts might suggest, that whilst the case should be made firm to resist a sharp point, the vibrations of that circular case might be prevented by lining it with a softer material; no bell would vibrate with such an incumbrance; the sound would be stopped like the ringing of a glass by the touch of a finger.

If a soldier's head be covered with a steel cap, the blow of a sword which does not penetrate will yet bring him to the ground by the percussion which extends to the brain; therefore, the helmet is lined with leather, and

covered with hair; for, although the hair is made an ornament, it is an essential part of the protection: we may see it in the head-piece of the Roman soldier, where all useless ornament, being despised as frivolous, was avoided as cumbrous.

We now perceive why the skull consists of two plates of bone, one external, which is fibrous and tough, and one internal, dense to such a degree that the anatomist calls it *tabula vitrea* (the glassy table).

Nobody can suppose this to be accidental. It has just been stated, that the brain may be injured in two ways: a stone or a hammer may break the skull, and the depressed part of the bone injure the brain; whilst, on the other hand, a mallet struck upon the head will, without penetrating, effectually deprive the brain of its functions, by causing a vibration which runs round the skull and extends to every portion of its contents.

Were the skull, in its perfect or mature state, softer than it is, it would be like the skull of a child; were it harder than we find it is, it would be like that of an old man. In other words, as in the former it would be too easily pierced, so, in the latter, it would vibrate too sharply and produce concussion. The skull of an infant is a single layer of elastic bone; on the approach to manhood it separates into two tables; and in old age it again becomes consolidated. During the active years of man's life the skull is perfect: it then consists of two layers united by a softer substance; the inner layer is brittle as glass, and calculated to resist anything penetrating; the outer table is tough, to give consistence, and to stifle the vibration which would take place if the whole texture were uniform and like the inner table.

The alteration in the substance of the bones, and more particularly in the skull, is marvellously ordered to follow the changes in the mind of the creature, from the heedlessness of childhood to the caution of age, and even the helplessness of superannuation.

The skull is soft and yielding at birth; during childhood it is elastic, and little liable to injury from concussion; and during youth, and up to the period of maturity,

the parts which come in contact with the ground are thicker, whilst the shock is dispersed towards the sutures (the seams or joinings of the pieces), which are still loose. But when, with advancing years, something tells us to give up feats of activity, and falls are less frequent, the bones lose that nature which would render concussion harmless, and at length the timidity of age teaches man that his structure is no longer adapted to active life.

We must understand the necessity of the double layer of the skull, in order to comprehend another very curious contrivance. The sutures are the lines of union of the several bones which form the *cranium*,* and surround and protect the brain. These lines of union are called ***sutures*** (from the Latin word for *sewing*), because they resemble seams. If a workman were to inspect the joining of two of the bones of the cranium, he would admire the minute dove-tailing by which one portion of the bone is inserted into, and surrounded by, the other, whilst that other pushes its processes or juttings out between those of the first in the same manner, and the fibres of the two bones are thus interlaced, as you might interlace your fingers. But when you look to the internal surface, you see nothing of this kind; the bones are here laid simply in contact, and this line by anatomists is called *harmonia*, or harmony: architects use the same term to imply the joining by masonry. Whilst the anatomists are thus curious in names, it is provoking to find them negligent of things more interesting. Having overlooked the reason of the difference in the tables of bone, they are consequently blind to the purpose of this difference of the outward and inward part of a suture.

Suppose a carpenter employed upon his own material, he would join a box with minute and regular indentations by dovetailing, because he knows that the material on

* *Cranium*, from a Greek word signifying a helmet. The cranium is the division of the skull appropriated to the protection of the brain; it consists of six bones—the *frontal* (or forehead); two *parietal* (walls or side bones); the *occipital* (back of the head); and two *temporal* (or temple) bones.

which he works, from its softness and toughness, admits of such adjustment of its edges. The processes of the bone shoot into the opposite cavity with an exact resemblance to the foxtail wedge of the carpenter—a kind of tenon and mortice when the pieces are small.

But if a workman in glass or marble were to inclose some precious thing, he would smooth the surfaces and unite them by cement, because, even if he could succeed in indenting the line of union, he knows that his material would chip off on the slightest vibration. The edges of the marble cylinders which form a column are, for the same reason, not permitted to come in contact; thin plates of lead are interposed to prevent the edges, technically termed *arrises*, from chipping off or splitting.

Now apply this principle to the skull. The outer softer tough table, which is like wood, is indented and dovetailed; the inner glassy table has its edges simply laid in contact. It is mortifying to see a course of bad reasoning obscure this beautiful subject. They say that the bone growing from its centre, and diverging, shoots its fibres betwixt those which come in an opposite direction; thus making one of the most curious provisions of nature a thing of accident. Is it not enough to ask such reasoners why there is not a suture on the inside as well as on the out?

The junction of the bones of the head generally being thus exact, and like the most finished piece of cabinet work, let us next inquire whether there be design or contrivance shown in the manner in which each bone is placed upon another.

When we look upon the side of the skull (as in the figure at p. 29), the temporal suture betwixt the bones A and D is formed in a peculiar manner; the lower, or temporal, bone laps over the superior, or parietal, bone. This, too, has been misunderstood: that is to say, the plan of the building of the bones of the head has not been considered; and this joining, called the squamous*

* From *squama*, the Latin for a *scale*, the thin edges lying over each other like the scales of a fish.

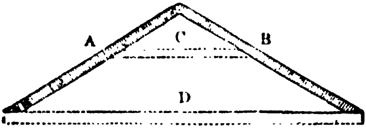
suture, which is a species of scarfing, has been supposed a mere consequence of the pressure of the muscle which moves the jaw.

Dr. Monro says, "the manner how I imagine this sort of suture is formed at these places, is, that by the action of the strong temporal muscles on one side, and by the pressure of the brain on the other, the bones are made so thin that they have not large enough surfaces opposed to each other to stop the extension of their fibres in length, and thus to cause the common serrated appearance of sutures; but the narrow edge of the one bone slides over the other."

The very name of the bones might suggest a better explanation. The *ossa parietalia* * are the two large bones in a regular square, serving as walls to the interior or room of the head, where the brain is lodged.—*See* A *in the foregoing figure.*

Did the reader ever notice how the walls of a house are assisted when thin and overburdened with a roof?

The *wall plate* is a portion of timber built into the wall, to which a transverse or tie-beam is attached by carpentry. This *cogging*, as it is termed, keeps the wall in the perpendicular, and prevents any lateral pressure of the roof. We sometimes see a more clumsy contrivance, a clasp, or a round plate of iron, upon the side of a wall; this has a screw going into the ends of a cross-beam, and by embracing a large portion of the brick-work, it holds the wall from shifting at this point. Or take the instance of a roof supported on inclined rafters, A B:



Were they thus, without further security, placed upon the walls, the weight would tend to spur or press out the

* From the Latin word *paries*, a wall.

walls, which must be strong and heavy to support the roof; therefore, the skeleton of the roof is made into a *truss* (for so the whole joined carpentry is called). The upper cross-beam marked by the dotted lines c, is a collar-beam, connecting the rafters of the roof, and stiffening them, and making the weight bear perpendicularly upon the walls. When the transverse beam joins the extremities of the rafters, as indicated by the lower outline D, it is called a *tie-beam*, and is more powerful still in preventing the rafters from pushing out the walls.

Now when a man bears a burden upon his head, the pressure, or horizontal push, comes upon the lower part of the *parietal bones*, and if they had not a tie-beam, they would, in fact, be spurred out, and the bones of the head be crushed down. But the temporal bone D, and still more, the sphenoid bone E, by running across the base of the skull, and having their edges lapping over the lower part of the great walls, or the parietal bones, lock in the walls as if they had iron plates, and answer the purpose of the tie-beam in the roof, or the iron plate in the walls. But the connexion is at the same time so secure, that these bones act equally as a *straining* piece, that is, as a piece of timber, preventing the tendency of the sides *of the skull* to each other.

It may be said, that the skull is not so much like the wall of a house as like the arch of a bridge: let us then consider it in this light.

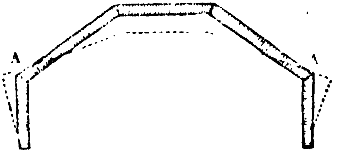
We have here the two parietal bones, separated and resting against each other, so as to form an arch. In the centering, which is the wooden frame for supporting a stone arch while building, there are some principles that are applicable to the head.

We see that the arch formed by the two parietal bones (see fig. at p. 30) is not a perfect semicircle; there is a projection at the centre of each bone, the bone is more convex, and thicker at this part.

The cause assigned for this is, that it is the point from which ossification begins, and where it is, therefore, most perfect. But this is to admit a dangerous principle,

that the forms of the bones are matter of chance: and thence we are left without a motive for study, and make no endeavour to comprehend the uses of parts. We find that all the parts which are most exposed to injury are thus strengthened;—the centre of the forehead, the projecting point of the skull behind, and the lateral centres of the parietal and frontal bones. The parts of the head which would strike upon the ground when a man falls are the strongest, and the projecting arch of the parietal bone is a protection to the weaker temporal bone.

If we compare the skull to the *centering*, where a bridge is to be built over a navigable river, and consequently where the space must be free in the middle, we find that the scientific workmen are careful, by a transverse beam, to protect the points where the principal thrust will be made in carrying up the masonry: this beam does not act as a tie-beam, but as a straining-piece, preventing the arch from being crushed in at this point.



The necessity of strengthening certain points is well exhibited in the carpentry of roofs. In this figure it is clear, that the points A A will receive the pressure of the roof, and if the joining of the puncheons* and rafters be not secure, it will sink down in the form of the dotted line. The workmen would apply braces at these angles to strengthen them.

In the arch, and at the corresponding points of the

* The puncheons are the upright lateral pieces; the rafters are the timbers which lie oblique, and join the puncheons at A A.

parietal bones, the object is attained by strengthening these points by increase of their convexity and thickness: and where the workman would support the angles by braces, there are ridges of bone, in the calvaria,* or roof of the skull.

If a stone arch fall, it must give way in two places at the same time; the centre cannot sink unless that part of the arch which springs from the pier yields: and in all arches, from the imperfect Roman arch to that built upon modern principles, the aim of the architect is to give security to this point.

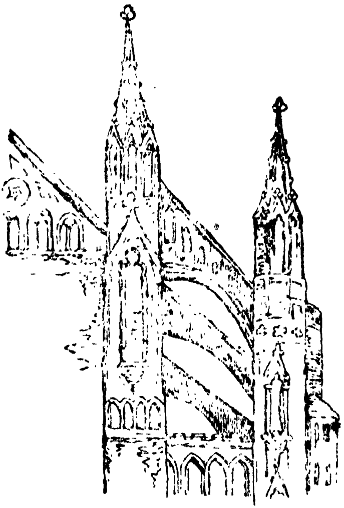
In the Roman bridges still entire the arch rises high, with little inclination at the lower part; and in bridges of a more modern date, we see a mass of masonry erected on the pier, sometimes assuming the form of ornament, sometimes of a tower or gateway, but obviously intended at the same time, by the perpendicular load, to resist the horizontal pressure of the arch. If this be omitted in more modern buildings, it is supplied by a finer art, which gives security to the masonry of the pier (to borrow the terms of anatomy) by its internal structure.

In what is termed Gothic architecture, we see a flying buttress, springing from the outer wall, carried over the roof of the aisle, and abutting against the wall of the upper part, or *clerestory*. From the upright part of this masonry a pinnacle is raised, which at first appears to be a mere ornament, but which is necessary, by its perpendicular weight, to counteract the horizontal thrust of the arch.

By all this, we see that if the skull is to be considered as an arch, and the parietal bones as forming that arch, they must be secured at the temporal and sphenoid†

* From the Latin *calva* or *calvaria*, a *helmet*.

† In the Greek, *sphenoid*—in the Latin, *cuneiform*—like a wedge, because it is wedged among the other bones of the head; but these processes, called wedges, are more like dovetails, which enter into the irregularities of the bones, and hold them locked.



bones, the points from which they spring. And, in point of fact, where is it that the skull yields when a man falls, so as to strike the top of his head upon the ground?—in the temples. And yet the joinings are so secure, that the extremity of the bone does not start from its connexions. It must be fractured before it is spurred out, and in that case only does the upper part of the arch yield.

But the best illustration of the form of the head is the dome.

A dome is a vault rising from a circular or elliptical base; and the human skull is, in fact, an elliptical surmounted dome, which latter term means that the dome is higher than the radius of its base. Taking this matter historically, we should presume that the dome was the

most difficult piece of architecture, since the first dome erected appears to have been at Rome, in the reign of Augustus—the Pantheon, which is still entire. The dome of St. Sophia, in Constantinople, built in the time of the Emperor Justinian, fell three times during its erection: and the dome of the Cathedral of Florence stood unfinished one hundred and twenty years for want of an architect. Yet we may, in one sense, say that every builder who tried it, as well as every labourer employed, had the most perfect model in his own head. It is obvious enough, that the weight of the upper part of the dome must disengage the stones from each other which form the lower circle, and tend to break up their joinings, and consequently to press or thrust outwards the circular wall on which it rests. No walls can support the weight, or rather, the lateral thrust, unless each stone of the dome be soldered to another, or the whole hooped together and girded. The dome of St. Paul's has a very strong double iron chain, linked together, at the bottom of the cone; and several other lesser chains between that and the cupola, which may be seen in the section of St. Paul's engraved by Hooker.

The bones of the head are securely bound together, so that the anatomist finds, when every thing is gone, save the bone itself, and there is neither muscle, ligament, nor membrane of any kind, to connect the bones, they are, still, securely joined, and it requires his art to burst them asunder; and for this purpose he must employ a force which shall produce a uniform pressure from the centre outwards; and all the sutures must receive the pressure at one time and equally, or they will not give way. And now is the time to observe another circumstance, which calls for our admiration. So little of accident is there in the joining of the bones, that the edge of a bone at the suture lies over the adjoining bone at one part and under it at another, which, with the dovetailing of the suture, as before described, holds each bone in its place firmly attached; and it is this which gives security to the dome of the cranium.

If we look at the skull in front, we may consider the orbits of the eye as crypts under the greater building. And these under-arches are groined, that is to say, there are strong arched spines of bone, which give strength sufficient to permit the interstices of the groinings, if I may so term them, to be very thin. Betwixt the eye and the brain, the bone is as thin as parchment; but if the anterior part of the skull had to rest on this, the foundation would be insufficient. This is the purpose of the strong ridge of bone which runs up like a buttress from the temple to the lateral part of the frontal bone, whilst the arch forming the upper part of the orbit is very strong: and these ridges of bone, when the skull is formed with what we call a due regard to security, give an extension to the forehead.*

In concluding this survey of the architecture of the head, let us suppose it so expanded that we could look upon it from within. In looking up to the vault, we should at once perceive the application of the *groin* in masonry; for the groin is that projection in the vault which results from the intersection of two arches running in different directions. One rib or groin extends from the centre of the frontal bone to the most projecting part of the occipital foramen, or opening on the back of the head; the other rib crosses it from side to side of the occipital bone. The point of intersection of these two groins is the thickest and strongest part of the skull, and it is the most exposed, since it is the part of the head which would strike upon the ground when a man falls backwards.

What is termed the base of the skull is strengthened, if we may so express it, on the same principle: it is like a cylinder groin, where the rib of an arch does not

* Although they are solid arches connected with the building of the cranium, and bear no relation to the surfaces of the brain, the early craniologists would have persuaded us that their forms correspond with the surfaces of the brain, and indicate particular capacities or talents.

terminate upon a buttress or pilaster, but is continued round in the completion of the circle. The base of the skull is irregular, and in many places thin and weak, but these arched spines or ribs give it strength to bear those shocks to which it is of course liable at the joining of the skull with the spine.

CHAPTER II.

MECHANISM OF THE SPINE.

The brain-case is thus a perfect whole, secure on all sides, and strengthened where the exposure to injury is the greatest. We shall see, in the column which sustains it, equal provision for the security of the brain; and, what is most admirable, there is an entirely different principle introduced here; for whereas in the head, the whole aim is firmness in the joinings of the bones, in the spine which supports the head, the object to be attained is mobility or pliancy. In the head, each bone is firmly secured to another; in the spine, the bones are not permitted to touch: there is interposed a soft and elastic material, which takes off the jar that would result from the contact of the bones. We shall consider this subject a little more in detail.

The spinal column, as it is called, serves three purposes: it is the great bond of union betwixt all the parts of the skeleton; it forms a tube for the lodgment of the spinal marrow, a part of the nervous system as important to life as the brain itself; and lastly, it is a column to sustain the head.

We now see the importance of the spine, and we shall next explain how the various offices are provided for.

If the protection of the spinal marrow had been the only object of this structure, it is natural to infer that it would have been a strong and unyielding tube of bone; but, as it must yield to the inflexions of the body, it cannot be constituted in so strict an analogy with the skull. It must, therefore, bend; but it must have no abrupt or considerable bending at one part; for the spinal marrow within would in this way suffer.

By this consideration we perceive why there are twenty-four bones in the spine, each bending a little; each articulated or making a joint with its fellow; all yielding in a slight degree, and, consequently, permitting in the whole spine that flexibility necessary to the motions of the body. It is next to be observed that, whilst the spine by this provision moves in every direction, it gains a property which it belongs more to our present purpose to understand. The bones of the spine are called vertebræ; at each interstice between these bones there is a peculiar gristly substance, which is squeezed out from betwixt the bones, and, therefore, permits them to approach and play a little in the motions of the body. This gristly substance is inclosed in an elastic binding, or membrane of great strength, which passes from the edge or border of one vertebra to the border of the one next it. When a weight is upon the body, the soft gristle is pressed out, and the membrane yields: the moment the weight is removed, the membranes recoil by their elasticity, the gristle is pressed into its place, and the bones resume their position.

We can readily understand how great the influence of these twenty-four joinings must be in giving elasticity to the whole column; and how much this must tend to the protection of the brain. Were it not for this interposition of elastic material, every motion of the body would produce a jar to the delicate texture of the brain, and we should suffer almost as much in alighting on our feet, as in falling on our head. It is, as we have already remarked, necessary to interpose thin plates of lead or slate between the different pieces of a column to prevent the edges (technically called arrises) of the cylinders from coming in contact, as they would, in that case, chip or split off.

But there is another very curious provision for the protection of the brain: we mean the curved form of the spine. If a steel spring, perfectly straight, be pressed betwixt the hands from its extremities, it will resist, notwithstanding its elasticity, and when it does give way, it will be with a jerk. Such would be the effect on the

spine if it stood upright, one bone perpendicular to another; for then the weight would bear equally; the spine would yield neither to one side nor to the other; and, consequently, there would be a resistance from the pressure on all sides being balanced. We, therefore, see the great advantage resulting from the human spine being in the form of an italic *ſ*. It is prepared to yield in the direction of its curves; the pressure is of necessity more upon one side of the column than on the other; and its elasticity is immediately in operation without a jerk. It yields, recoils, and so forms the most perfect spring; admirably calculated to carry the head without jar, or injury of any kind.

The most unhappy illustration of all this is the condition of old age. The tables of the skull are then consolidated, and the spine is rigid: if an old man should fall with his head upon the carpet, the blow, which would be of no consequence to the elastic frame of a child, may to him prove fatal; and the rigidity of the spine makes every step which he takes vibrate to the interior of the head, and jar on the brain.

We have hinted at a comparison betwixt the attachment of the spine to the pelvis and the insertion of the mast of a ship into the hull. The mast goes directly through the decks without touching them, and the heel of the mast goes into the step, which is formed of large solid pieces of oak timber laid across the keelson. The keelson is an inner keel resting upon the floor-timbers of the ship and directly over the proper keel. These are contrivances for enlarging the base on which the mast rests as a column: for as, in proportion to the height and weight of a column, its base must be enlarged, or it would sink into the earth; so, if the mast were to bear upon a point, it would break through the bottom of the ship.

The mast is supported upright by the shrouds and stays. The shrouds secure it against the lateral or rolling motion, and the stays and backstays against the pitching of the ship. These form what is termed the standing rigging. The mast does not bear upon the deck or

on the beams of the ship; indeed there is a space covered with canvas betwixt the deck and the mast.

We often hear of a new ship going to sea to stretch her rigging; that is, to permit the shrouds and stays to be stretched by the motion of the ship, after which they are again braced tight: for if she were overtaken by a storm before this operation, and when the stays and shrouds were relaxed, the mast would lean against the upper deck, by which it would be sprung or carried away. Indeed, the greater proportion of masts that are lost are lost in this manner. There are no boats which keep the sea in such storms as those which navigate the gulf of Finland. Their masts are not attached at all to the hull of the ship, but simply rest upon the step.

Although the spine has not a strict resemblance to the mast, the contrivances of the ship-builder, however different from the provisions of nature, show what object is to be attained; and when we are thus made aware of what is necessary to the security of a column on a moveable base, we are prepared to appreciate the superior provisions of nature for giving security to the human spine.

The human spine rests on what is called the *pelvis*, or basin;—a circle of bones, of which the haunches are the extreme lateral parts; and the sacrum (which is as the keystone of the arch) may be felt at the lower part of the back. To this central bone of the arch of the pelvis the spine is connected; and, taking the similitude of the mast, the sacrum is as the *step* on which the base of the pillar, like the heel of the mast, is socketed or mortised. The spine is tied to the lateral parts of the pelvis by powerful ligaments, which may be compared to the shrouds. They secure the lower part of the spine against the shock of lateral motion or rolling; but, instead of the stays to limit the play of the spine forwards and backwards in pitching, or to adjust the rake of the mast, there is a very beautiful contrivance in the lower part of the column.

The spine forms here a semicircle which has this effect; that, whether by the exertion of the lower extremities, the spine is to be carried forward upon the

pelvis, or whether the body stops suddenly in running, the jar which would necessarily take place at the lower part of the spine A, if it stood upright like a mast, is distributed over several of the bones of the spine, 1, 2, 3, 4, and, therefore, the chance of injury at any particular part is diminished.

For example, the sacrum, or centre bone of the pelvis, being carried forward, as when one is about to run, the force is communicated to the lowest bone of the spine. But, then, the surfaces of these bones stand with a very slight degree of obliquity to the line of motion; the shock communicated from the lower to the second bone of the vertebræ is still in a direction very nearly perpendicular to its surface of contact. The same takes place in the communication of force from the second to the third, and from the third to the fourth; so that before the shock of the horizontal motion acts upon the perpendicular spine, it is distributed over four bones of that

column, instead of the whole force being concentrated upon the joining of any two, as at A.

If the column stood upright, as indicated at C D, it would be jarred at the lowest point of contact with its base. But by forming a semicircle A B, the motion which in the direction E F would produce a jar on the very lowest part of the column, is distributed over a considerable portion of the column A B; and in point of fact, this part of the spine never gives way. Indeed, we should be inclined to offer this mode to the consideration of nautical men, as fruitful in hints for improving naval architecture.

Every one who has seen a ship pitching in a heavy sea, must have asked himself why the masts are not upright, or rather, why the foremast stands upright, whilst the main and mizen masts stand oblique to the deck, or, as the phrase is, rake aft or towards the stern of the ship.

The main and mizen masts incline backwards, because the strain is greatest in the forward pitch of the vessel; for the mast having received an impulse forwards, it is suddenly checked as the head of the ship rises; but the mast being set with an inclination backwards, the motion falls more in the perpendicular line from the head to the heel. This advantage is lost in the upright position of the foremast, but it is sacrificed to a superior advantage gained in working the ship; the sails upon this mast act more powerfully in swaying the vessel round, and the perpendicular position causes the ship to tack or stay better; but the perpendicular position, as we have seen, causes the strain in pitching to come at right angles to the mast, and is, therefore, more apt to spring it.

These considerations give an interest to the fact, that the human spine, from its utmost convexity near its base, inclines backwards.

CHAPTER III.

OF THE CHEST.

In extending the parallel which we proposed between the structure of the body and the works of human art, it signifies very little to what part we turn; for the happy adaptation of means to the end will everywhere challenge our admiration, in exact proportion to our success in comprehending the provisions which Supreme Wisdom has made. We turn now to a short view of the bones of the chest.

The thorax, or chest, is composed of bones and cartilages, so disposed as to sustain and protect the most vital parts, the heart and lungs, and to turn and twist with perfect facility in every motion of the body; and to be in incessant motion in the act of respiration, without a moment's interval during a whole life. In anatomical description, the thorax is formed of the vertebral column, or spine, on the back part, the ribs on either side, and the breastbone, or sternum, on the fore part. But the thing most to be admired is the manner in which these bones are united, and especially the manner in which the ribs are joined to the breastbone, by the interposition of cartilages, or gristle, of a substance softer than bone, and more elastic and yielding. By this quality they are fitted for protecting the chest against the effects of violence, and even for sustaining life after the muscular power of respiration has become too feeble to continue without this support.

If the ribs were complete circles, formed of bone, and extending from the spine to the breastbone, life would be endangered by any accidental fracture; and even the rubs and jolts to which the human frame is continually

exposed, would be too much for their delicate and brittle texture. But these evils are avoided by the interposition of the elastic cartilage. On their forepart the ribs are eked out, and joined to the breastbone by means of cartilages, of a form corresponding to that of the ribs, being, as it were, a completion of the arch of the rib, by a substance more adapted to yield in every shock or motion of the body. The elasticity of this portion subdues those shocks which would occasion the breaking of the ribs. We lean forward, or to one side, and the ribs accommodate themselves, not by a change of form in the bones, but by the bending or elasticity of the cartilages. A severe blow upon the ribs does not break them, because their extremities recoil and yield to the violence. It is only in youth, however, when the human frame is in perfection, that this pliancy and elasticity have full effect. When old age approaches, the cartilages of the ribs become bony. They attach themselves firmly to the breastbone, and the extremities of the ribs are fixed, as if the whole arch were formed of bone unyielding and inelastic. Then every violent blow upon the side is attended with fracture of the rib, an accident seldom occurring in childhood, or in youth.

But there is a purpose still more important to be accomplished by means of the elastic structure of the ribs, as partly formed of cartilage. This is in the action of breathing, or respiration; especially in the more highly-raised respiration which is necessary in great exertions of bodily strength, and in violent exercise. There are two acts of breathing—*expiration*, or the sending forth of the breath; and *inspiration*, or the drawing in of the breath. When the chest is at rest, it is neither in the state of expiration nor in that of inspiration; it is in an intermediate condition between these two acts. And the muscular effort by which either inspiration or expiration is produced is an act in opposition to the elastic property of the ribs. The property of the ribs is to preserve the breast in the intermediate state between expiration and inspiration. The muscles of respiration are excited alternately, to dilate or to contract the cavity of the chest,

and, in doing so, to raise or to depress the ribs. Hence it is, that both in inspiration and in expiration the elasticity of the ribs is called into play; and, were it within our province, it would be easy to show, that the dead power of the cartilages of the ribs preserves life by respiration, after the vital muscular power would, without such assistance, be too weak to continue life.

It will at once be understood, from what has now been explained, how, in age, violent exercise or exertion is under restraint, in so far as it depends on respiration. The elasticity of the cartilages is gone, the circle of the ribs is now unyielding, and will not allow that high breathing, that sudden and great dilating and contracting of the cavity of the chest, which is required for circulating the blood through the lungs, and relieving the heart amidst the more tumultuous flowing of the blood which exercise and exertion produce.

CHAPTER IV.

DESIGN SHOWN IN THE STRUCTURE OF THE BONES AND JOINTS OF THE EXTREMITIES.

THAT the bones, which form the interior of animal bodies, should have the most perfect shape, combining strength and lightness, ought not to surprise us, when we find this in the lowest vegetable production.

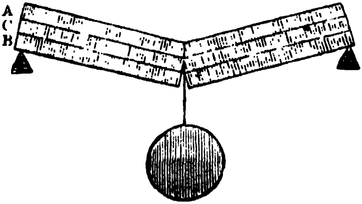
In the sixteenth century, an unfortunate man who taught medicine, philosophy, and theology, was accused of atheistical opinions, and condemned to have his tongue cut out, and to suffer death. When brought from his cell before the Inquisition, he was asked if he believed in God. Picking up a straw which had stuck to his garments, "If," said he, "there was nothing else in nature to teach me the existence of a Deity, even this straw would be sufficient!"*

[A reed, or a quill, or a bone, may be taken to prove that in Nature's works strength is given with the least possible expense of materials. The long bones of animals are, for the most part, hollow cylinders, filled up with the lightest substance, marrow; and in birds the object is attained by means (if we may be permitted to say so) still more artificial. Every one must have observed, that the breast-bone of a fowl extends along the whole body, and that the body is very large compared with the weight: this is for the purpose of rendering the creature specifically lighter and more buoyant in the air; and that it may have a surface for the attachment of muscles, equal to the exertion of raising it on the wing. This combina-

* The passage following, marked in brackets, on to p. 189, appears also in Sir C. Bell's Illustrations of Paley, p. 18. It could not be removed from its present place without disturbing the coherence of the argument.

tion of lightness with increase of volume is gained by air-cells extending through the body, and communicating by tubes between the lungs and cavities of the bones. By these means, the bones, although large and strong to withstand the operation of powerful muscles upon them, are much lighter than those of quadrupeds.

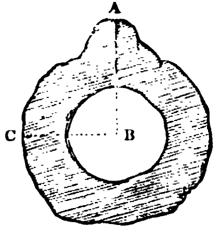
The long bones of the human body, being hollow tubes, are called cylindrical, though they are not accurately so, the reason of which we shall presently explain; and we shall, at the same time, show that their irregularities are not accidental, as some have imagined. But let us first demonstrate the advantage which, in the structure of the bones, is derived from the cylindrical form, or a form approaching to that of the cylinder. If a piece of timber supported on two points, thus—



bear a weight upon it, it sustains this weight by different qualities in its different parts. For example, divide it into three equal parts (A, B, C): the upper part A supports the weight by its solidity and resistance to compression; the lowest part B, on the other hand, resists by its toughness, or adhesive quality. Betwixt the portions acting in so different a manner there is an intermediate neutral, or central part C, that may be taken away without materially weakening the beam, which shows that a hollow cylinder is the form of strength. The Writer lately observed a good demonstration of this:—a large tree was blown down, and lay upon the ground; to the windward, the broken part gaped; it had been torn asunder like the snapping of a rope: to the leeward side of the tree, the fibres of the stem were crushed into one

another and splintered; whilst the central part remained entire. This, we presume, must be always the case, more or less; and here we take the opportunity of noticing why the arch is the form of strength. If this transverse piece of timber were in the form of an arch, and supported at the extremities, then its whole thickness, its centre, as well as the upper and lower parts, would support weight by resisting compression. But the demonstration may be carried much farther to show the form of strength in the bone. If the part of the cylinder which bears the pressure be made more dense, the power of resistance will be much increased; whereas, if a ligamentous covering be added on the other side, it will strengthen the part which resists extension: and we observe a provision of this kind in the tough ligaments which run along the vertebræ of the back.

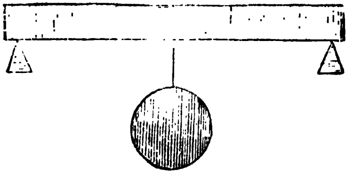
When we see the bone cut across, we are forced to acknowledge that it is formed on the principle of the cylinder; that is, that the material is removed from the centre, and accumulated on the circumference, thus—



We find a spine, or ridge running along the bone, which, when divided by the saw in a transverse direction, exhibits an irregularity, as at A.

The section of this spine shows a surface as dense as ivory, which is, therefore, much more capable of resisting compression than the other part of the cylinder, which is common bone. This declares what the spine is, and the anatomists must be wrong who imagine that the bone is moulded by the action of the muscle, and

that the spine is a mere ridge, arising by accident among the muscles. It is, on the contrary, a strengthening of the bone in the direction on which the weight bears. If we resume the experiment with the piece of timber, we shall learn why the spine is harder than the rest of the bone. If a portion of the upper part of the timber be cut away, and a harder wood inserted in its place, the beam will acquire a new power of resisting fracture, because, as we have stated, this part of the wood does not yield but by being crushed, and the insertion of the



harder portion of wood increases this property of resistance. With this fact before us we may return to the examination of the spine of bone. We see that it is calculated to resist pressure, first, because it is farther removed from the centre of the cylinder; and, secondly, because it is denser, to resist compression, than the other part of the circumference of the bone.*

This explanation of the use of a spine upon a bone gives a new interest to osteology.† The anatomist ought to deduce from the form of the spine the motions of the limb; the forces bearing upon the bone, and the nature and the common place of fracture; while to the general inquirer an agreeable process of reasoning is introduced in that department, which is altogether without interest when the "*irregularities*" of the bone are spoken of, as

* As the line A B extends farther from the centre than B C, on the principle of a lever, the resistance to transverse fracture will be greater in the direction A B than B C.

† *Osteology*, from the Greek words, signifying discourse on bone, being the demonstration of the forms and connexion of the different bones.

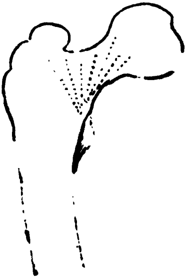
if they were the accidental consequences of the pressure of the flesh upon it.

Although treating of the purely mechanical principle, it is, perhaps, not far removed from our proper object to remark, that a person of feeble texture and indolent habits has the bone smooth, thin, and light; but that Nature, solicitous for our safety, in a manner which we could not anticipate, combines with the powerful muscular frame a dense and perfect texture of bone, where every spine and tubercle is completely developed. And thus the inert and mechanical provisions of the bone always bear relation to the muscular power of the limb, and exercise is as necessary to the perfect constitution of a bone as it is to the perfection of the muscular power. Jockeys speak correctly enough, when they use the term "*blood and bone*," as distinguishing the breed or genealogy of horses; for blood is an allowable term for the race, and bone is so far significant, that the bone of a running horse is remarkably compact compared with the bone of a draught horse. The reader can easily understand, that the span in the gallop must give a shock in proportion to its length; and as in man, so in the horse, the greater the muscular power the denser and stronger is the bone.

The bone not being as a mere pillar, intended to bear a perpendicular weight, we ought not to expect uniformity in its shape. Each bone, according to its place, bears up against the varying forces that are applied to it. Consider two men wrestling together, and then think how various the property of resistances must be: here they are pulling, and the bones are like ropes; or again, they are writhing and twisting, and the bones bear a force like the axle-tree between two wheels; or they are like a pillar under a great weight; or they are acting as a lever.]

To withstand these different shocks, a bone consists of three parts, the *earth* of bone (sub-phosphate of lime); *fibres* to give it toughness; and *cartilage* to give it elasticity. These ingredients are not uniformly mixed up in all bones; but some bones are hard, from the prevalence of the earth of bone; some more fibrous, to resist

a pull upon them; and some more elastic, to resist the shocks in walking, leaping, &c. But to return to the forms:—Whilst the centre of the long bones is, as we have stated, cylindrical, their extremities are expanded, and assume various shapes. The expansion of the head of the bone is to give a greater, and consequently a more secure surface for the joint, and its form regulates the direction in which the joint is to move. A jockey, putting his hand on the knee of a colt, and finding it broad and flat, augurs the perfection of the full-grown horse. To admit of this enlargement and difference of form, a change in the internal structure of the bone is necessary, and the hollow of the tube is filled up with *cancelli*, or lattice-work. These *cancelli* of the bone are minute and delicate, like wires, which form lattice-work, extending in all directions through the interior of the bone, and which, were it elastic, would be like a sponge.—This more uniform texture of the bone permits the outer shell to be very thin, so that whilst the centre of the long bones are cylinders, their extremities are of a uniform cancellated structure. But it is pertinent to our purpose to notice, that this minute lattice-work, or the cancelli which constitute the interior structure of bone, have still reference to the forces acting on the bone; if any



The head of the thigh-bone, to show the direction of the *cancelli*, converging to the line of gravity.

one doubts this, let him make a section of the upper and lower end of the thigh-bone, and let him inquire what is the meaning of the difference in the *lie* of these minute bony fibres, in the two extremities? He will find that the head of the thigh-bone stands obliquely off from the shaft, and that the whole weight bears on what is termed the *inner trochanter:* and to that point, as to a buttress, all these delicate fibres converge, or point from the head and neck of the bone, which may be rudely represented in this way. (See fig., p. 190.)

We may here notice an opinion that has been entertained, in regard to the size of animals. It is believed that the material of bone is not capable of supporting a creature larger than the elephant, or the *mastodon*, which is the name of an extinct animal of great size, the osseous remains of which are still found. This opinion is countenanced by observing that their bones are very clumsy, that their spines are of great thickness, and that their hollow cylinders are almost filled up with bone.

It may be illustrated in this manner;—A soft stone projecting from a wall may make a stile, strong enough to bear a person's weight; but if it were necessary to double its length, the thickness must be more than doubled, or a freestone substituted; and were it necessary to make this freestone project twice as far from the wall, even if doubled in thickness, it would not be strong enough to bear a proportioned increase of weight: granite must be placed in its stead; and even the granite would not be capable of sustaining four times the weight which the soft stone bore in the first instance. In the same way the stones which form an arch of a large span must be of the hardest granite, or their own weight would crush them. The same principle is applicable to the bones of animals. The material of bone is too soft to admit an indefinite increase of weight; and it is another illustration of what was before stated, that there is a relation established through all nature, and that the very animals which move upon the surface of the earth are proportioned *to its magnitude*, and the gravitation to its centre. Archdeacon Paley has with great propriety taken the instance of the form of the ends of bones, as proving

design in the mechanism of a joint. But there is something so highly interesting in the conformation of the whole skeleton of an animal, and the adaptation of any one part to all the other parts, that we must not let our readers remain ignorant of the facts, or of the important conclusions drawn from them.

What we have to state has been the result of the studies of many naturalists; but although they have laboured, as it were, in their own department of comparative anatomy, they have failed to seize upon it with the privilege of genius, and to handle it in the masterly manner of Cuvier.

Suppose a man ignorant of anatomy to pick up a bone in an unexplored country, he learns nothing, except that some animal has lived and died there; but the anatomist can, by that single bone, estimate, not merely the size of the animal, as well as if he saw the print of its foot, but the form and joints of the skeleton, the structure of its jaws and teeth, the nature of its food, and its internal economy. This, to one ignorant of the subject, must appear wonderful, but it is after this manner that the anatomist proceeds: let us suppose that he has taken up that portion of bone in the limb of the quadruped which corresponds to the human wrist; and that he finds that the form of the bone does not admit of free motion in various directions, like the paw of the carnivorous creature. It is obvious, by the structure of the part, that the limb must have been merely for supporting the animal, and for progression, and not for seizing prey. This leads him to the fact that there were no bones resembling those of the hand and fingers, or those of the claws of the tiger; for the motions which that conformation of bones permits in the paw would be useless without the rotation of the wrist—he concludes that these bones were formed in one mass, like the cannon-bone, pastern-bone, and coffin-bones of the horse's foot.*

* For these are solid bones, where it is difficult to recognise any resemblance to the carpus, metacarpus, and bones of the fingers; and yet comparative anatomy proves that these moveable bones are of the same class with those in the solid hoof of the *belluæ* of Linnæus.

The motion limited to flexion and extension of the foot of a hoofed animal implies the absence of a collar-bone, and a restrained motion in the shoulder joint; and thus the naturalist, from the specimen in his hand, has got a perfect notion of all the bones of the anterior extremity! The motions of the extremities imply a condition of the spine which unites them. Each bone of the spine will have that form which permits the bounding of the stag, or the galloping of the horse, but it will not have that form of joining which admits the turning or writhing of the spine, as in the leopard or the tiger.

And now he comes to the head:—the teeth of a carnivorous animal, he says, would be useless to rend prey, unless there were claws to hold it, and a mobility of the extremities like the hand, to grasp it. He considers, therefore, that the teeth must have been for bruising herbs, and the back teeth for grinding. The socketing of these teeth in the jaw gives a peculiar form to these bones, and the muscles which move them are also peculiar; in short, he forms a conception of the shape of the skull. From this point he may set out anew, for by the form of the teeth he ascertains the nature ot the stomach, the length of the intestines, and all the peculiarities which mark a vegetable feeder.

Thus the whole parts of the animal system are so connected with one another, that from one single bone or fragment of bone, be it of the jaw, or of the spine, or of the extremity, a really accurate conception of the shape, motions, and habits of the animal, may be formed.

It will readily be understood that the same process of reasoning will ascertain, from a small portion of a skeleton, the existence of a carnivorous animal, or of a fowl, or of a bat, or of a lizard, or of a fish; and what a conviction is here brought home to us, of the extent of that plan which adapts the members of every creature to its proper office, and yet exhibits a system extending through the whole range of animated beings, whose motions are conducted by the operation of muscles and bones.

After all, this is but a part of the wonders disclosed through the knowledge of a thing so despised as a frag-

ment of bone. It carries us into another science; since the knowledge of the skeleton not only teaches us the classification of creatures now alive, but affords proofs of the former existence of animated beings which are not now to be found on the surface of the earth. We are thus led to an unexpected conclusion from such premises: not merely the existence of an individual animal, or race of animals; but even the changes which the globe itself has undergone in times before all existing records, and before the creation of human beings to inhabit the earth, are opened to our contemplation.

Of Standing.

This may appear to some a very simple inquiry, and yet it is very ignorant to suppose that it is so. The subject has been introduced in this fashion:—"Observe these men engaged in raising a statue to its pedestal with the contrivances of pulleys and levers, and how they have placed it on the pedestal and are soldering it to keep it steady, lest the wind should blow it down. This statue has the fair and perfect proportions of the human body; to all outward appearance it ought to stand."

In the following passage we have the same idea thrown out in a manner which we are apt to call *French*. Were a man cast on a desert shore, and there to find a beautiful statue of marble, he would naturally exclaim,—"Without doubt, there have been inhabitants here: I recognise the hand of a famous sculptor: I admire the delicacy with which he has proportioned all the members of the body to give them beauty, grace, and majesty, to indicate the motion and expression of life." But it may be asked, what would such a man think if his companion were to say,—"Not at all—no sculptor made this statue; it is formed, to be sure, in the best taste, and according to the rules of art, but it is formed by chance: amongst the many fragments of marble, there has been one thus formed of itself. The rain and the winds have detached it from the mountain, and a storm has placed it upright on the pedestal. The pedestal, too, was prepared of itself in this lonely place. True, it is like the Apollo, or

the Venus, or the Hercules. You might believe that the figure lived and thought; that it was prepared to move and speak; but it owes nothing to art; blind chance has placed it there." *

The first passage suggests the conviction that the power of standing proceeds not from any symmetry, as in a pillar, or from gravitation alone. It, in fact, proceeds from an internal provision, by which a man is capable of estimating, with great precision, the inclination of his body, and correcting the bias by the adjustment of the muscles. In the second passage, it is meant to be shown that the outward proportion of the form bears a relation to the internal structure; that grace and expression are not superficial qualities, and that only the Divine Architect could form such a combination of animated machinery.

We shall consider how the human body is prepared by mechanical contrivances to stand upright, and by what fine sense of the gravitation of the body the muscles are excited to stiffen the otherwise loose joints, and to poise the body on its base.

Of the Foot.

Let us take the arrangement of the bones of the foot, according to the demonstration of the anatomists.

They are divided into the *tarsus*, which is composed of seven bones, reaching from the heel to the middle of the foot. The *metatarsus*, which consists of five long bones laid parallel to each other, and extending from the *tarsus* to the roots of the toes. The bones of the toes are called *phalanges*, from being in the form of a *phalanx.*

There are in all thirty-six bones in the foot; and the first question that naturally arises, is, why should there be so many bones? The answer is, In order that there may be so many joints; for the structure of a joint not only permits motion, but bestows elasticity.

A joint then consists of the union of two bones, of such a form as to permit the necessary motion: but they

* *Démonstration de l'Existence de Dieu, par Fénélon.*

are not in contact: each articulating surface is covered with cartilage, to prevent the jar which would result from the contact of the bones. This cartilage is elastic, and the celebrated Dr. Hunter discovered that the elasticity was in consequence of a number of filaments closely compacted, and extending from the surface of the bone, so that each filament is perpendicular to the pressure made upon it. The surface of the articulating cartilage is perfectly smooth, and is lubricated by a fluid called *synovia*, signifying a mucilage, a viscous or thick liquor. This is vulgarly called *joint-oil*, but it has no property of oil, although it is better calculated than any oil to lubricate the interior of the joint.

When inflammation comes upon a joint, this fluid is not supplied, and the joint is stiff, and the surfaces creak upon one another like a hinge without oil. A delicate membrane extends from bone to bone, confining this lubricating fluid, and forming the boundary of what is termed the cavity of the joint, although, in fact, there is no unoccupied space. External to this capsule* of the joint there are strong ligaments going from point to point of the bones, and so ordered as to bind them together without preventing their proper motions. From this description of a single joint, we can easily conceive what a spring or elasticity is given to the foot, where thirty-six bones are jointed together.

An elegant author has this very natural remark on the joints:—"In considering the joints, there is nothing, perhaps, which ought to move our gratitude more than the reflection, *how well they wear*. A limb shall swing upon its hinge, or play in its socket, many hundred times in an hour, for sixty years together, without diminution of its agility, which is a long time for anything to last, for anything so much worked and exercised as the joints are. This durability I should attribute, in part, to the provision which is made for the preventing of wear and tear: first, by the polish of cartilaginous surfaces; secondly, by the healing lubrication of the mucilage; and,

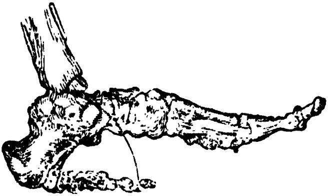
* From *capsula*, a little case, or box.

in part, to that astonishing property of animal constitutions, assimilation, by which, in every portion of the body, let it consist of what it will, substance is restored and waste repaired."—*Paley*.

If the ingenious author's mind had been professionally called to contemplate this subject, he would have found another explanation. There is no resemblance betwixt the provisions against the wear and tear of machinery and those for the preservation of a living part. As the structure of the parts is originally perfected by the action of the vessels, the function or operation of the part is made the stimulus to those vessels. The cuticle on the hands wears away like a glove; but the pressure stimulates the living surface to force successive layers of skin under that which is wearing, or, as the anatomists call it, desquamating; by which they mean, that the cuticle does not change at once, but comes off in *squamæ*, or scales. The teeth are subject to pressure in chewing or masticating, and they would, by this action, have been driven deeper in the jaw, and rendered useless, had there not been a provision against this mechanical effect. This provision is a disposition to grow, or rather to shoot out of their sockets; and this disposition to project, balances the pressure which they sustain; and when one tooth is lost, its opposite rises, and is in danger of being lost also, for want of that very opposition.

The most obvious proof of contrivance is the junction of the foot to the bones of the leg at the ankle joint. The two bones of the leg, called the *tibia* and the *fibula*, receive the great articulating bone of the foot (the *astragalus*) betwixt them. And the extremities of these bones of the leg project so as to form the outer and inner ankle. Now, when we step forward, and whilst the foot is raised, it rolls easily upon the ends of these bones, so that the toe may be directed according to the inequalities of the ground we are to tread upon; but when the foot is planted, and the body is carried forward perpendicularly over the foot, the joint of the leg and foot becomes fixed, and we have a steady base to rest

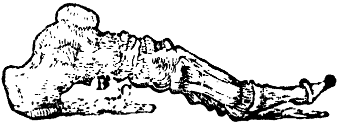
upon. We next observe, that, in walking, the heel first touches the ground. If the bones of the leg were perpendicular over the part which first touches the ground, we should come down with a sudden jolt, instead of which we descend in a semicircle, the centre of which is the point of the heel.



And when the toes have come to the ground we are far from losing the advantages of the structure of the foot, since we stand upon an elastic arch, the hinder extremity of which is the heel, and the anterior the balls of the toes. A finely formed foot should be high in the instep. The walk of opera dancers is neither natural nor beautiful; but the surprising exercises which they perform give to the joints of the foot a freedom of motion almost like that of the hand. We have seen the dancers, in their morning exercises, stand for twenty minutes on the extremities of their toes, after which the effort is to bend the inner ankle down to the floor, in preparation for the Bolero step. By such unnatural postures and exercises the foot is made unfit for walking, as may be observed in any of the retired dancers and old *figurantes*. By standing so much upon the toes, the human foot is converted to something more resembling that of a quadruped, where the heel never reaches the ground, and where the paw is nothing more than the phalanges of the toes.

This arch of the foot, from the heel to the toe, has the astragalus (A) resembling the keystone of an arch; but, instead of being fixed, as in masonry, it plays freely

betwixt two bones, and from these two bones, B and C, a strong elastic ligament is extended, on which the bone (A) rests, sinking or rising as the weight of the body bears upon it, or is taken off, and this it is enabled to do by the action of the ligament which runs under it.



This is the same elastic ligament which runs extensively along the back of the horse's hind leg and foot, and gives the fine spring to it, but which is sometimes ruptured by the exertion of the animal in a leap, producing irrecoverable lameness.

Having understood that the arch of the foot is perfect from the heel to the toe, we have next to observe, that there is an arch from side to side; for when a transverse section is made of the bones of the foot, the exposed surface presents a perfect arch of wedges, regularly formed like the stones of an arch in masonry. If we look down upon the bones of the foot, we shall see that they form a complete circle horizontally, leaving a space in their centre. These bones thus form three different arches—forward, across, and horizontally: they are wedged together, and bound by ligaments, and this is what we alluded to when we said that the foundations of the Eddystone were not laid on a better principle; but our admiration is more excited in observing, that the bones of the foot are not only wedged together, like the courses of stone for resistance, but that solidity is combined with elasticity and lightness.

Notwithstanding the mobility of the foot in some positions, yet when the weight of the body bears directly over it, it becomes immoveable, and the bones of the leg must be fractured before the foot yields.

We shall proceed to explain how the knee-joint and

hip-joint, independently of the exertion of muscles, become firm in the standing position, and when at rest: but, before we enter upon this, let us understand the much talked-of demonstration of Borelli, who explained the manner in which a bird sits upon a branch when asleep—the weight of the creature, and the consequent flexion of the limbs, drawing the tendons of the talons, so as to make them grasp the branch without muscular effort.

The muscle A passing over the joint at B, and then proceeding to the back of the leg, and behind the joint at C, and so descending behind the foot at D, it extends to the talons; and the weight of the bird, bending the joint B and C, produces the effect of muscular effort, and makes the claws cling.

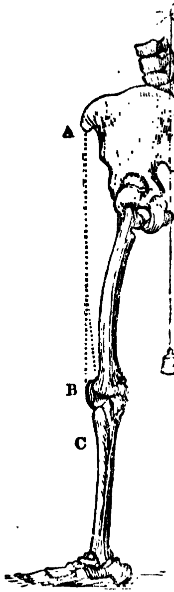
But why should the anatomist have recourse to this piece of comparative anatomy, when he has so fine an example in the human body? And one which is much more interesting, as, in fact, it is the foundation of

reasoning upon the diseases and accidents of the limb. If this beautiful arrangement in the healthy and perfect structure of a man's limb be not attended to, it would be easy to prove that many important circumstances, in regard to disease and accidents, must remain obscure.

The posture of a soldier under arms, when his heels are close together, and his knees straight, is a condition of painful restraint. Observe, then, the change in the body and limbs, when he is ordered to stand at ease; the firelock falls against his relaxed arms, the right knee is thrown out, and the tension of the ankle joint of the same leg is relieved, whilst he loses an inch and a half of his height, and sinks down upon his left hip. This command to "stand at ease" has a higher authority than the general orders. It is a natural relaxation of all the muscles; which are, consequently, relieved from a painful state of exertion: and the weight of the body bears so upon the lower extremity, as to support the joints independently of muscular effort. The advantage of this will be understood, when we consider that all muscular effort is made at the expense of a living power, which, if excessive, will exhaust and weary a man, whilst the position of rest which we are describing is without effort, and therefore gives perfect relief. And it is this which makes boys and girls, who are out of health and languid, lounge too much in the position of relief, from whence comes permanent distortion.

The following figure represents the bones of the leg.

The plumb-line shows the direction of the gravitation of the body falling behind the head of the thighbone. Now, if it be understood that the motions of the trunk are performed on the centre of the head of the thighbone, it must follow that the weight of the body in the direction of the plumb-line must raise the corner of the haunch-bone, at A. From this corner of the bone, a broad and strong band runs down to the knee-pan, B, in the direction of the dotted line. The powerful muscles which extend the leg are attached to the knee-pan, and through the ligament at C, operate on the bones of the leg, stretching them, and preventing the flexion of the



joint; but, in the absence of the activity of these muscles, the band reaching from A to B, drawn, as we have said, by the weight of the body, is equivalent to the exertion of the muscles, braces the knee-joint, and extends the leg; and we have before seen that the extension of the leg fixes the ankle-joint. Thus the limb is made a firm pillar under the weight of the body, without muscular effort.

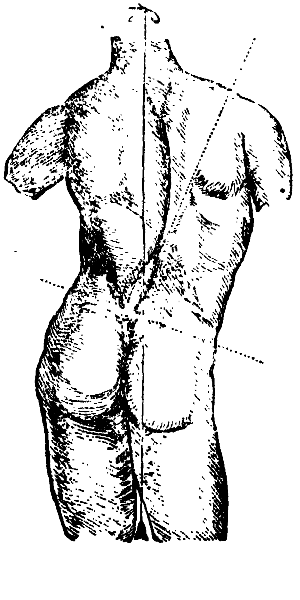
When the human figure is left to its natural attitudes, we see a variety and contrast in the position of the trunk and limbs.

This position of the body resting on the lower extre-

mities throws the trunk into an elegant line, and places the limbs in beautiful contrast, as we see in all the best specimens of sculpture. (See below.)

Now that we have understood that the lower extremity becomes in some positions a firm pillar, it is the more necessary to observe the particular form of the head of the thigh-bone. (See next page.)

It is here seen that the head of the bone A stands off from the shaft by the whole length of the neck of the bone B; the effect of this is, that as the powerful muscles are attached to the knobs of bone C D, they turn the thigh-bone round in walking with much greater power than if the head of the bone were on a line with the shaft. They, in fact, acquire a lever power by the

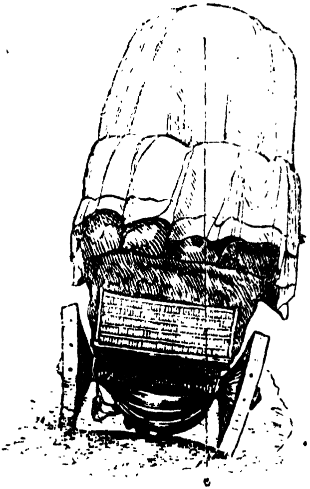


distance of D from A; as, during the action of these muscles, the limb is stiff, the rolling of the thigh directs the toe outwards in walking.

When the weight of the body is perpendicularly over the ball of the great toe, the whole body is twisted round on that point as on a pivot. This rolling of the body on the ball of the toe, and consequent turning out of the toes in stepping forward, is necessary to the freedom and elasticity of the motion. The form of all the bones of the leg, and the direction of all the muscles of the thigh and leg, combine to this effect. So far is it from being true, as painters affect to say, that the turning out of the toes is the result of the lessons of the dancing-master.

A certain squareness in the position of the feet is consistent with strength, as we see in the statues of the Hercules, &c.; but the lightness of a Mercury is indicated by the direction of the toes outwards. In women, there would be a defect from the breadth of the pelvis,

and a rolling and an awkward gait would be the consequence; but in them the foot is more turned out, and a light, elastic step balances the defect arising from the form of the pelvis. Any one may be convinced of this by observing people who walk awkwardly, especially if they walk unequally. Look at their feet, and you will see that one foot goes straight forward, whilst the other is turned outwards, and that when they come upon the straight foot, they come down awkwardly, and have no spring from it.

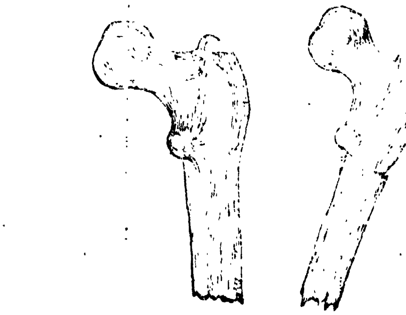


There is another curious circumstance in the form of the thigh-bone, showing how it is calculated for strength as well as freedom of motion. To understand it, we must first look to the *dishing* of a wheel—the dishing is the oblique position of the spokes from the nave to the felly, giving the wheel a slightly conical form. When a cart is in the middle of a road, the load bears equally

upon both wheels, and both wheels stand with their spokes oblique to the line of gravitation.

If the cart is moving on the side of a barrel-shaped road, or if one wheel falls into a rut, the whole weight comes upon one wheel: but the spokes of that wheel, which were oblique to the load when it supported only one-half of the weight, are now perpendicular under the pressure, and are capable of sustaining the whole. If roads were made perfectly level, and had no holes in them, the wheels of carts might be made without dishing; but if a cart is calculated for a country road, let the wheelwright consider what equivalent he has to give for that very pretty result proceeding from the obliquity of the spokes, or *dishing* of the wheel.

When we return to consider the human thigh-bone, we see that the same principle holds; that is to say, that whilst a man stands on both his legs, the necks of the thigh-bones are oblique to the line of gravitation of the body; but when one foot is raised, the whole body then being balanced on one foot, a change takes place in the position of the thigh-bone, and the obliquity of that bone is diminished; or, in other words, now that it has the whole weight to sustain, it is perpendicular under it, and has therefore acquired greater strength. (See below.)



CHAPTER V.

OF THE TENDONS COMPARED WITH CORDAGE.

Where nature has provided a perfect system of columns, and levers, and pullies, we may anticipate that the cords by which the force of the muscles is concentrated on the moveable bones must be constructed with as curious a provision for their offices. In this surmise we shall not be disappointed.

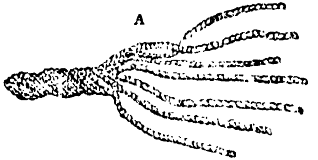
To understand what is necessary to the strength of a rope or cable we must learn what has been the object of the improvements and patents in this manufacture. The first process in rope-making, is hatchelling the hemp; that is, combing out the short fibres, and placing the long ones parallel to one another. The second is, spinning the hemp into yarns. And here the principle must be attended to, which goes through the whole process in forming a cable; which is that the fibres of the hemp shall bear an equal strain: and the difficulty may be easily conceived, since the twisting must derange the parallel position of the fibres. Each fibre, as it is twisted, ties the other fibres together, so as to form a continued line, and it bears at the same time a certain portion of the strain, and so each fibre alternately. The third step of the process is making the yarns. Warping the yarns, is stretching them to a certain length; and for the same reason that so much attention has been paid to the arrangement of the fibres for the yarns, the same care is taken in the management of the yarns for the strands. The fourth step of the process is to form the strands into ropes. The difficulty of the art has been to make them bear alike, especially in great cables, and this has been the object of patent machinery. The

hardening, by twisting, is also an essential part of the process of rope-making; for without this, it would be little better than extended parallel fibres of hemp. In this twisting, first of the yarns, and then of the strands, those which are on the outer surface must be more stretched than those near the centre; consequently, when there is a strain upon the rope, the outer fibres will break first, and the others in succession. It is to avoid this, that each yarn and each strand, as it is twisted or hardened, shall be itself revolving, so that when drawn into the cable, the whole component parts may, as nearly as possible, resist the strain in an equal degree; but the process is not perfect, and this we must conclude from observing how different the construction of a tendon is from that of a rope. A tendon consists of a strong cord, apparently fibrous; but which, by the art of the anatomist, may be separated into lesser cords, and these, by maceration, can be shown to consist of cellular membrane, the common tissue that gives firmness to all the textures of the animal body. The peculiarity here results merely from its remarkable condensation. But the cords of which the larger tendon consists do not lie parallel to each other, nor are they simply twisted like the strands of a rope; they are, on the contrary, plaited or interwoven together.

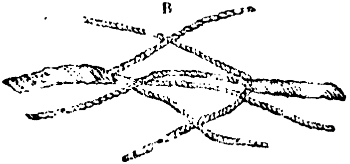
If the strong tendon of the heel, or Achilles tendon, be taken as an example, on first inspection it appears to consist of parallel fibres, but by maceration these fibres are found to be a web of twisted cellular texture. If you take your handkerchief, and slightly twisting it, draw it out like a rope, it will seem to consist of parallel cords; such is, in fact, so far the structure of a tendon. But, as we have stated, there is something more admirable than this, for the tendon consists of subdivisions, which are like the strands of a rope; but instead of being twisted simply as by the process of hardening, they are plaited or interwoven in a way that could not be imitated in cordage by the turning of a wheel. Here then is the difference,—by the twisting of a rope, the strands cannot resist the strain equally, whilst we see

that this is provided for in the tendon by the regular interweaving of the yarn, if we may so express it, so that every fibre deviates from the parallel line in the same degree, and, consequently, receives the same strain when the tendon is pulled. If we seek for examples illustrative of this structure of the tendons, we must turn to the subject of ship-rigging, and see there how the seaman contrives, by undoing the strands and yarns of a rope, and twisting them anew, to make his splicing stronger than the original cordage. A sailor opens the ends of two ropes thus;* and places the strand of one

A



B



opposite and between the strand of another, and so interlaces them. And this explains why a hawser-rope, a sort of small cable, is spun of *three* strands; for as they are necessary for many operations in the rigging of a ship, they must be formed in a way that admits of being cut and spliced, for the separation of three strands, at least, is necessary for knotting, splicing, whipping, mail-

* A, Strands and Yarns opened.
B, Ends opened and laid for splicing, in a manner exactly like the interlacing of the tendon.

ing, &c., which are a few of the many curious contrivances for joining the ends of ropes, and for strengthening them by filling up the interstices to preserve them from being cut or frayed. As these methods of splicing and plaiting in the subdivisions of the rope make an intertexture stronger than the original rope, it is an additional demonstration, if any were wanted, to show the perfection of the cordage of an animal machine, since the tendons are so interwoven; and until the yarns of one strand be separated and interwoven with the yarns of another strand, and this done with regular exchange, the most approved patent ropes must be inferior to the corresponding part of the animal machinery.

A piece of cord of a new patent has been shown to us, which is said to be many times stronger than any other cord of the same diameter. It is so far upon the principle here stated, that the strands are plaited instead of being twisted; but the tendon has still its superiority, for the lesser yarns of each strand in it are interwoven with those of other strands. It, however, gratifies us to see, that the principle we draw from the animal body is here confirmed. It may be asked, do not the tendons of the human body sometimes break? They do; but in circumstances which only add to the interest of the subject. By the exercise of the tendons, (and their exercise is the act of being pulled upon by the muscles, or having a strain made on them,) they become firmer and stronger; but in the failure of muscular activity, they become less capable of resisting the tug made upon them, and if, after a long confinement, a man has some powerful excitement to muscular exertion, then the tendon breaks. An old gentleman, whose habits have been long staid and sedentary, and who is very guarded in his walk, is upon an annual festival tempted to join the young people in a dance; then he breaks his tendo Achillis. Or a sick person, long confined to bed, is, on rising, subject to a rupture or hernia, because the tendinous expansions guarding against protrusion of the internal parts have become weak from disuse.

Such circumstances remind us that we are speaking of

a living body, and that, in estimating the properties of the machinery, we ought not to forget the influence of life, and that the natural exercise of the parts, whether they be active or passive, is the stimulus to the circulation through them, and to their growth and perfection.

CHAPTER VI.

OF THE MUSCLES—OF MUSCULARITY AND ELASTICITY.

There are two powers of contraction in the animal frame—elasticity, which is common to living and dead matter, and the muscular power, which is a property of the living fibre.

The muscles are the only organs which properly have the power of contraction, for elasticity is never exerted but in consequence of some other power bending or stretching the elastic body. In the muscles, on the contrary, motion originates; there being no connexion, on mechanical principles, betwixt the exciting cause and the power brought into action.

The real power is in the muscles, while the safeguard against the excess of that power is in the elasticity of the parts. This is obvious in the limbs and general texture of the frame; but it is most perfectly exhibited in the organs of circulation. If the action of the heart impelled the blood against parts of solid texture, they would quickly yield. When, by accident, this does take place, even the solid bone is very soon destroyed. But the coats of the artery which receive the rush of blood from the heart, although thin, are limber and elastic; and by this elasticity or yielding they take off or subdue the shock of the heart's action, while no force is lost; for as the elastic artery has yielded to the sudden impulse of the heart, it contracts by elasticity in the interval of the heart's pulsation; and the blood continues to be propelled onward in the course of the circulation, without interval, though regularly accelerated by the pulse of the heart.

If a steam-engine were used to force water along the

water-pipes, without the intervention of some elastic body, the water would not flow continuously, but in jerks, and, therefore, a reservoir is constructed containing air, into which the water is forced, against the elasticity of the air. Thus, each stroke of the piston is not perceptibly communicated to the conduit-pipe, because the intervals are supplied by the push of the compressed air. The office of the reservoir containing air is performed in the animal body by the elasticity of the coats of the arteries, by which means the blood which flows interruptedly into the arteries has a continuous and uninterrupted flow in the veins beyond them.

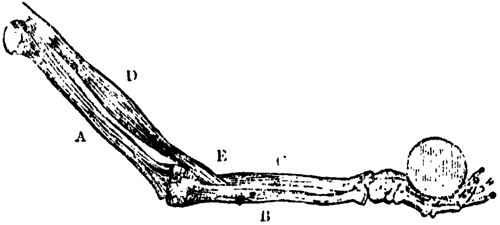
A muscle is fibrous, that is, it consists of minute threads bundled together, the extremities of which are connected with the tendons which have been described. Innumerable fibres are thus joined together to form one muscle, and every muscle is a distinct organ. Of these distinct muscles for the motions of the body there are not less than 436 in the human frame, independent of those which perform the internal vital motions. The contractile power which is in the living muscular fibre, presents appearances which, though familiar, are really the most surprising of all the properties of life. Many attempts have been made to explain this property, sometimes by chemical experiment, sometimes on mechanical principles, but always in a manner repugnant to common sense. We must be satisfied with saying, that it is an endowment, the cause of which it would be as vain to investigate as to resume the search into the cause of gravitation.

The ignorance of the cause of muscular contraction does not prevent us from studying the laws which regulate it, and under this head are included subjects of the highest interest; which, however, we must leave, to pursue the mechanical arrangement of the muscles.

Since we have seen that there are 436 distinct muscles in the body, it is due to our readers to explain how they are associated to effect that combination which is necessary to the motion of the limbs and to our perfect enjoyment. In the first place, the million of fibres, which

constitute a single muscle, are connected by a tissue of nerves, which produce a union or sympathy amongst them, so that one impulse causes a simultaneous effort of all the fibres attached to the same tendon. When we have understood that the muscles are distinct organs of motion, we perceive that they must be classed and associated in order that many shall combine in one act; and that others, their opponents, shall be put in a state to relax, and offer no opposition to those which are active. These relations can only be established through *nerves*, which are the organs of communication with the brain, or sensorium. The nerves convey the will to the muscles, and at the same time they class and arrange them so as to make them consent to the motions of the body and limbs.

On first looking to the manner in which the muscles are fixed into the bones, and the course of their tendons, we observe everywhere the appearance of a sacrifice of mechanical power, the tendon being inserted into the bone in such a manner as to lose the advantage of the lever. This appears to be an imperfection, until we learn that there is an accumulation of vital power in the muscle in order to attain velocity of movement in the member.

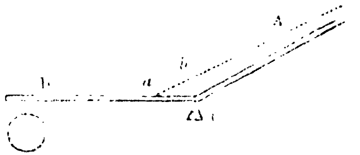


The muscle D, which bends the fore-arm, is inserted into the radius E, so near the fulcrum, or centre of motion in the elbow joint, and so oblique that it must

raise the hand and fore-arm with disadvantage. But, correctly speaking, the power of the muscle is not sacrificed, since it gains more than an equivalent in the rapid and lively motions of the hand and fingers, and since these rapid motions are necessary to us in a thousand familiar actions; and to attain this, the Creator has given sufficient vital power to the muscles to admit of the sacrifice of the mechanical or lever power, and so to provide for every degree and variety of motion which may answer to the capacities of the mind.

If we represent the bones and muscles of the fore-arm by this diagram, we shall see that power is lost by the inclination of the tendon to the lever, into which it is inserted. It represents the lever of the third kind, where the moving power operates on a point nearer the fulcrum than the weight to be moved.

Here A represents the muscle, B the lever, and C the fulcrum. The power of the muscle is not represented by the distance of its insertion *a*, from the fulcrum C. The

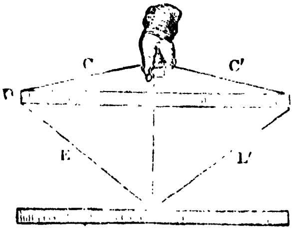


line which truly represents the lever must pass from the centre of motion, perpendicularly to the line of the tendon, viz., C, *b*. Here, again, by the direction of the tendon, as well as by its actual attachment to the bone, power is lost and velocity gained.

We may compare the muscular power to the weight which impels a machine. In studying machinery, it is manifest that weight and velocity are equivalent. The handle of the winch in a crane is a lever, and the space through which it moves, in comparison with the slow motion of the weight, is the measure of its power. If

the weight, raised by the crane, be permitted to go down, the wheels revolve, and the handle moves with the velocity of a cannon-ball, and will be as destructive if it hit the workman. The weight here is the power, but it operates with so much disadvantage, that the hand upon the handle of the winch can stop it: but give it way, let the accelerated motion take place, and the hand would be shattered which touched it. Just so the fly-wheel, moving at first slowly, and an impediment to the working of a machine, at length acquires momentum, so as to concentrate the power of the machine, and enable it to cut bars of iron with a stroke.

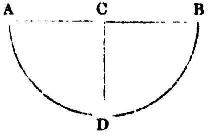
The principle holds in the animal machinery. The elbow is bent with a certain loss of mechanical power; but by that very means, when the loss is supplied by the living muscular power, the hand descends through a greater space, moves quicker, with a velocity which enables us to strike or to cut. Without this acquired velocity, we could not drive a nail: the mere muscular power would be insufficient for many actions quite necessary to our existence.



Let us take some examples to show what objects are attained through the oblique direction of the fibres of the muscle, and we shall see that here, as well as by the mode of attachment of the entire muscle, velocity is attained by the sacrifice of power. Suppose these two pieces of wood to be drawn together by means of a cord, but that the hand which pulls, although pos-

sessing abundant strength, wants room to recede more than what is equal to one third of the space betwixt the pieces of wood; it is quite clear, that if the hand were to draw direct on the cord A, B, the point A would be brought towards B, through one third only of the intervening space, and the end would not be accomplished. But if the cord were put over the ends of the upper piece, C, D, E, and, consequently, directed obliquely to their attachment at A, on drawing the hand back a very little, but with more force, the lower piece of wood would be suddenly drawn up to the higher piece, and the object attained. Or we may put it in this form:—If a muscle be in the direction of its tendon, the motion of the extremity of the tendon will be the same with that of the muscle itself: but if the attachment of the muscle to the tendon be oblique, it will draw the tendon through a greater space; and if the direction of the muscle deviate so far from the line of the tendon as to be perpendicular to it, it will then be in a condition to draw the tendon through the greatest space with the least contraction of its own length.

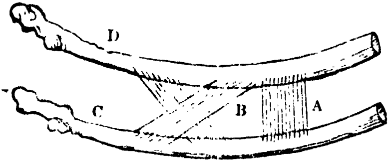
Thus, if A, B be a tendon, and C, D a muscle; by the contraction of C to D the extremities of the tendon A, B



will be brought together, through a space double the contraction of the muscle. It is the adjustment, on the same principle, which gives the arrow so quick an impulse from the spring of the bow, the extremities of the bow drawing obliquely on the string.

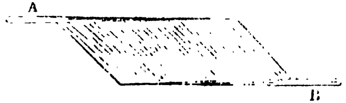
To free breathing, it is necessary that the ribs shall approach each other, and this is performed by certain *intercostal* muscles (or muscles playing between the ribs), and now we can answer the question, Why are the fibres of these muscles oblique?

Let us suppose this figure to represent two ribs with thin intervening muscles. If the fibres of the muscle were in the direction A, across, and perpendicular to the ribs;



and if they were to contract one-third of their length, they would not close the intervening space—they would not accomplish the purpose. But being oblique, as at B, although they contract no more than one-third of their length, they will bring the ribs C, D together. By this obliquity of the intercostal muscles, they are enabled to expand the chest in inspiration, in a manner which could not be otherwise accomplished.

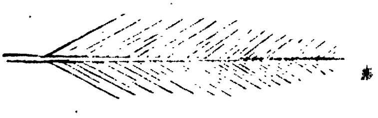
In the greater number of muscles the same principle directs the arrangement of the fibres; they exchange power for velocity of movement, by their obliquity. They do not go direct from origin to insertion, but obliquely, thus, from tendon to tendon:—



Supposing the point A to be the fixed point, these fibres draw the point B with less force, but through a larger space, or more quickly than if they took their course in direct lines; and by this arrangement of the fibres the freedom and extent of motion in our limbs are secured.

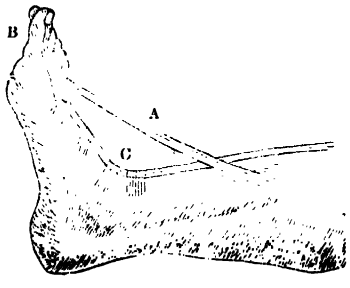
But the muscles must be strengthened by additional courses of fibres, because they are oblique; since by their obliquity they lose something of their force of action:

and therefore it is, we must presume, that we find them in a double row, making what is termed the *penniform* muscle, thus,—



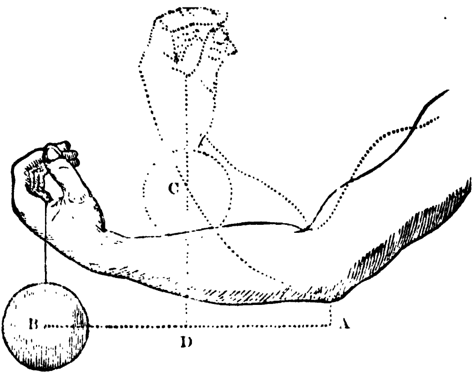
and sometimes the texture of the muscle is still further compounded by the intermixture of tendons, which permit additional series of fibres; and all this for the obvious purpose of accumulating power, which may be exchanged for velocity of movement.

We may perceive the same effect to result from the course of the tendons, and their confinement in sheaths, strengthened by cross-straps of ligament. If the tendon, A, took the shortest course to its termination at



B, it would draw up the toe with greater force; but then the toe would lose its velocity of movement. By taking the direction C, close to the joints, the velocity of motion is secured, and by this arrangement the toes possess their spring, and the fingers their lively movements. We may take this opportunity of noticing how the mechanical opposition is diminished as the living muscular power is

exhausted. For example, in lifting a weight, the length of the lever of resistance will be from the centre of the elbow joint, A, to the centre of the weight, B. As the muscles of the arm contract, they lose something of their power; but in a greater proportion is the mechanical resistance diminished, for when the weight is raised to C A D, it becomes the measure of the lever of resistance.



A more admirable thing is witnessed by the anatomist—we mean the manner in which the lever, rising or falling, is carried beyond the sphere of action of one class of muscles, and enters the sphere of activity of others. And this adaptation of the organs of motion is finely adjusted to the mechanical resistance which may arise from the form or motion of the bones. In short, whether we contemplate the million of fibres which constitute one muscle, or the many muscles which combine to the movement of the limb, nothing is more surprising and admirable than the adjustment of their power so as to balance mechanical resistance, arising from the change of position of the levers.

In the animal body, there is a perfect relation preserved betwixt the parts of the same organ. The muscular fibres forming what is termed the belly of the muscle, and the tendon through which the muscle pulls, are two parts of one organ; and the condition of the tendon indicates the state of the muscle. Thus jockeys discover the qualities of a horse by its sinews or tendons. The most approved form in the leg of the hunter, or hackney, is that in which three convexities can be distinguished,—the bone; the prominence of the elastic ligament behind the bone; and behind that the flexor tendons, large, round, and strong. Strong tendons are provided for strong muscles, and the size of these indicates the muscular strength. Such muscles, being powerful flexors, cause high and round action, and such horses are safe to ride; their feet are generally preserved good, owing to the pressure they sustain from their high action. But this excellence in a horse will not make him a favourite at Newmarket. The circular motion cannot be the swiftest; a blood-horse carries his foot near the ground. The speed of a horse depends on the strength of his loins and hind quarter; and what is required in the fore-legs is strength of the extensor tendons, so that the feet may be well thrown out before, for if these tendons be not strong, the joints will be unable to sustain the weight of his body, when powerfully thrown forward, by the exertion of his hind-quarters, and he will be apt to come with his nose to the ground.

The whole apparatus of bones and joints being thus originally constituted by Nature in accurate relation to the muscular powers, we have next to observe, that this apparatus is preserved perfect by exercise. The tendons, the sheaths in which they run, the cross ligaments by which they are restrained, and the *bursæ mucosæ* * which are interposed to diminish friction, can be seen in perfection only when the animal machinery has been kept

* These *bursæ mucosæ* (mucous purses) are sacs containing a lubricating fluid. They are interposed wherever there is much pressure or friction, and answer all the purposes of friction-wheels in machinery.

in full activity. In inflammation, and pain, and necessary restraint, they become weak; and even confinement, and want of exercise, without disease, will produce imperfections. Exercise unfolds the muscular system, producing a full bold outline of the limbs, at the same time that the joints are knit, small, and clean. In the loins, thighs, and legs of a dancer we see the muscular system fully developed; and when we turn our attention to his puny and disproportioned arms, we acknowledge the cause—that, in the one instance, exercise has produced perfection, and that, in the other, the want of it has occasioned deformity. Look to the legs of a poor Irishman travelling to the harvest with bare feet: the thickness and roundness of the calf show that the foot and toes are free to permit the exercise of the muscles of the leg. Look, again, to the leg of our English peasant, whose foot and ankle are tightly laced in a shoe with a wooden sole, and you will perceive, from the manner in which he lifts his legs, that the play of the ankle, foot, and toes is lost, as much as if he went on stilts, and, therefore, are his legs small and shapeless.

And this brings us naturally to a subject of some interest at present: we mean the new fashion of exercising our youth in a manner which is to supersede dancing, fencing, boxing, rowing, and cricket, and the natural impulse of youth to activity.

By this fashion of training to what are termed *gymnastics*, children at school are to be urged to feats of strength and activity, not restrained by parental authority, nor left to their own sense of pleasurable exertion. They are made to climb, to throw their limbs over a bar, to press their foot close to their hip, their knees close to their stomach; to hang by the arms and raise the body, —to hang by the feet and knees,—to struggle against each other, by placing the soles of their feet in opposition, and to pull with their hands. No doubt, if such exercises be persevered in, the muscular powers will be strongly developed. But the first question to be considered is the safety of this practice. We have seen a professor of gymnastics, by such training, acquire great

strength and prominence of muscles; but by this unnatural increase of muscular power, through the exercises he recommended, he became ruptured on both sides. The same accident has happened to boys too suddenly put on these efforts.

It is proper to observe, that when the muscular power is thus, we may say, preternaturally increased, whether in the instance of a race-horse, an opera-dancer, or a pupil of the Calisthenic school, it is not merely necessary to put them on their exercises gradually in each successive lesson, but each day's exertion must be preceded by a wearisome preparation. In the great schools, like that at Stockholm, the master makes the boys walk in a circle; then run, at first gently; and so he gradually brings them into heat, and the textures of their frame are composed to that state of elasticity and equal resistance, as well as to vital energy, which is necessary for the safe display of the greater feats of strength and activity. This caution in the public exercises is the very demonstration of the dangers of the system. The boys will not be always under this severe control, and yet it is important to their safety.

We may learn how necessary it is to bring the animal system gradually into action from the effects of very moderate exercise on a horse just out of the dealer's hands. The purchaser thinks he may safely drive him ten miles, not aware that the horse has not moved a mile in a week, and the consequence is, inflammation and congestion in his lungs. The regulation in the army has been made on a knowledge of these facts. When young horses are brought from the dealer they are ordered to be walked an hour a-day the first week, two hours a-day the second week, three hours a-day in the third week. They are to be fatigued by walking, but they must not be sweated in their exercise. Horses for the turf, under three years old, in training for the Derby, are brought very slowly to their exercise, beginning with the lounge; then a very light weight is put upon them, and that gradually increased. Indeed, nothing can better show the effects of

exercise in perfecting the muscular action than the consequence of the loss of one day's training. It will bring the favourite to the bottom of the list, and that without any suspicion of lameness, but from a knowledge of the fact, that even such a slight irregularity in his training will have a sensible effect on his speed. Shall the possibility of pecuniary loss excite the jockey to more care for his horse than we, in our rational and humane attention to the education of our youth, pay to their health and safety?

In reflecting on these many proofs of design in the animal body, it must excite our surprise that anatomy is so little cultivated by men of science. We crowd to see a piece of machinery or a new engine, but neglect to raise the covering which would display in the body the most striking proofs of design, surpassing all art in simplicity and effectiveness, and without any thing useless or superfluous.

A more important deduction from the view of the animal structure is, that our conceptions of the perfection and beauty in the design of nature are exactly in proportion to the extent of our capacity. We are familiar with the mechanical powers, and we recognise the principles in the structure of the animal machine; and in proportion as we understand the principles of hydrostatics and hydraulics, are able to discern the most beautiful adaptation of them in the vessels of an animal body. But when, to our further progress in anatomy, it is necessary that we should study a matter so difficult as the theory of life, imperfect principles or wrong conceptions distort and obscure the appearances: false and presumptuous theories are formed, or we are thrown back in disappointment into scepticism, as if chance only could produce that, of which we do not comprehend the perfect arrangement. But studies better directed, and prosecuted in a better spirit, prove that the human body, though deprived of what gave it sense and motion, is still a plan drawn in perfect wisdom.

A man possessed of that humility which is akin to true

knowledge, may be depressed by too extensive a survey of the frame of nature. The stupendous changes which the geologist surveys — the incomprehensible magnitude of the heavenly bodies moving in infinite space, bring down his thoughts to a painful sense of his own littleness: "to him the earth with men upon it will not seem much other than an ant-hill, where some ants carry corn, and some carry their young, and some go empty, and all to and fro—a little heap of dust." *

He is afraid to think himself an object of Divine care; but when he regards the structure of his own body, he learns to consider space and magnitude as nothing to a Creator. He finds that the living being, which he was about to contemn, in comparison with the great system of the universe, exists by the continuance of a power, no less admirable than that which rules the heavenly bodies; he sees that there is a revolution, a circle of motions no less wonderful in his own frame, in the microcosm of man's body than in the planetary system; that there is not a globule of blood which circulates, but possesses attraction as incomprehensible and wonderful as that which retains the planets in their orbits.

The economy of the animal body, as the economy of the universe, is sufficiently known to us to compel us to acknowledge an Almighty power in the creation. What would be the consequence of a further insight—whether it would conduce to our peace or happiness—whether it would assist us in our duties, or divert us from the performance of them, is very uncertain.

* Bacon.

PART II.

SHOWING THE APPLICATION OF THE LIVING FORCES.

Amongst the least informed people, and in remote villages, there are old saws and rules regarding health, sickness, and wounds, which might be thought to come from mere experience; but they are, on the contrary, for the most part, the remains of forgotten theories and opinions, laid down by the learned of former days. Portions of knowledge, it would appear, confined at first to a select part of society, are, in the progress of time, diffused generally, and may be recognised in the aphorisms of the poor. These are traced to their source only by the curious few, who like to read old books, and to observe how that which is originally right, becomes, through prejudice and ignorance, distorted and fantastical.

If a very little exact knowledge of the structure of our own frames were more generally diffused, charity would be advanced, empirics could hardly maintain their influence, and medical men might have a farther motive to desire professional eminence.

Men suppose that the knowledge of their own bodies must be a science locked up from them, because of the language in which it is conveyed; or they take away their thoughts from it, as from the contemplation of danger, unwilling to survey the slight ties by which they hold their lives. They are like persons for the first time at sea, who shudder to calculate how many circumstances must concur to speed the frail vessel on its voyage, and how little is between them and the deep. It is then a mean and timid spirit that shuts out from our contemplation the finest proofs of Divine Providence. Galen's treatise on the uses of the parts of the human body

was composed as a hymn to the Creator, and abounds in demonstrations of a Supreme Cause; and when Cicero desires to prove the existence of the Deity from the order and beauty of the universe, he surveys the body of man, deeming nothing more godlike, as marking man's superiority to the brutes, than the privilege of contemplating his own condition, since it teaches him the ways of Providence, from a knowledge of which come piety and all the virtues.

Although we are writing under the title of Animal Mechanics, the reader must be aware that we cannot proceed much farther, on mechanical principles alone. At least, before we have it in our power to illustrate particular parts of the animal frame, by reference to those principles, we must have the proofs before us that we are considering a living body. It is the principle of *life* which distinguishes the studies of the physiologist from the other branches of natural knowledge. To lose sight of this distinction is to tread back the path, and to engage once more in the vain endeavour to explain the phenomena of life on mechanical principles. We have taken mechanics in their application to mechanical structure in the living body, because they give obvious proofs of design, and in a manner that admits of no cavil. Yet, although those proofs are very clear in themselves, they are not so well calculated to warm and exalt our sentiments as these which we have now to offer in taking a wider view of the animal economy.

In entering on the second department of this treatise, the reader may be startled at the subjects of discussion; but this comes also from ignorance of their nature. Much may be learned from the observation of things familiar. Their perpetual recurrence banishes reflection respecting them, but it is the business of philosophy to make us alive to the importance of that which we have been accustomed to from childhood, and have, therefore, long ceased to observe with attention.

In the first chapter of this second part we shall continue to examine the operations of the animal body, independently of the agency of the living property. We

shall consider it as a mere hydraulic machine. Following the blood in its circle through cisterns and conduit pipes, we shall point out the application of the principles of this science as we formerly did those of mechanics, and so arrive at the like conclusions by a different course. And as we before found every muscular fibre adjusted with mechanical precision, so now we shall find every branch of an artery, or of a vein, taking that precise course and direction which the experience of the engineer shows to be necessary in laying the pipes of an engine.

Having thus surveyed the mechanical operations of the animal body, and the course of the fluids conveyed through it, on hydraulic principles, we shall consider ourselves as having advanced through the meaner to the higher objects of inquiry, and proceed to show how the principle of life bestows different endowments on the framework; how motion originates in a manner quite different from that produced by mechanical forces; how the sensibilities animate the living properties of action; how the different endowments of life correspond with each other, and exhibit power and design in a degree far superior to any thing that we observed in the mechanical adjustment of the parts, or the circulation of the fluids.

CHAPTER I.

THE CIRCULATION OF THE BLOOD, UPON THE PRINCIPLES OF HYDRAULICS.

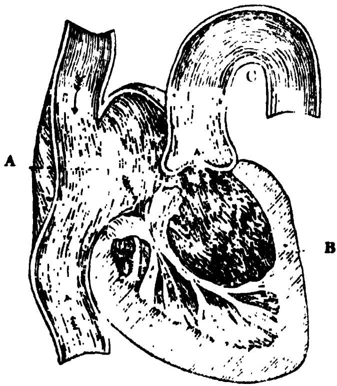
In tracing the course of the circulation of the blood, it is natural to inquire how far the system of reservoirs, pipes, and valves, which form the apparatus for conveying it, are constructed on the principles of hydraulics.

We find this difficulty in the outset, that the vessels containing the blood are not rigid, like those the engineer employs in erecting hydraulic machinery. Instead of resembling pipes which convey water, and which receive the force of gravitation on them, they have both elasticity and an appropriate living power. The artery, the tube which conveys the blood out from the heart to the body, has a property of action in itself. Its elasticity and muscular power must derange those influences which we study in pure hydraulics.

There is to be found, notwithstanding, a great deal that is common to both, when we compare the tubes of an animal body with the hydraulic engine; the capacity of the vessels; the increase, or diminution, of their calibres; their curves; the direction of their branches; —all these ought still to be on the same principles on which experience has taught men to form conduit pipes. We ought not to be indifferent to these proofs of design, because we acknowledge that an infinitely superior power is brought into operation in the animal body, and which is necessary to the circulation of the blood. It renders the inquiry more difficult, but it does not obscure the inferences drawn from the consideration of the whole subject.

We shall first present to our readers the simplest form

of the Heart. It is not necessary to detail the more complicated structure of the human heart, where, in fact, two hearts are combined; the fibres of the one continued into the fibres of the other, and the tubes twisting round one another so as to present the form which is familiar to everybody. Although there are four intricate cavities, seven tubes conveying the blood into them, and two conveying it out of them, we shall, for the purpose of considering the forces circulating the blood, and comparing the living vessels with pipes, present the heart and vessels as simple; yet, with perfect truth, being, in fact, the heart and vessels of animals of more simple structure.



The action of the heart is this: the blood returns from the body by veins into the sinus or auricle,* A, and distends it: this sinus is surrounded with muscular fibres; by the distention or elongation of these fibres they are excited,

* Auricle, from *auricula*, the flap of the ear, is a name given to the sinus, because a corner of it hangs over like a dog's ear.

and the sinus contracts and propels the blood into the ventricle, B. The ventricle is more muscular; it is, in fact, a powerful hollow muscle; it is excited by the distention, and contracts and propels the blood into the artery, C.

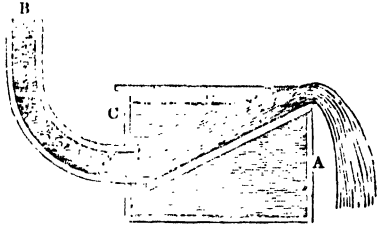
We understand then that every heart must, at least, consist of two cavities alternating in their action; that the vessel which carries the blood to them is called a vein; and that the vessel which carries the blood out from them is the artery.

The first thing that strikes a person examining the heart is the extraordinary intricacy of the cavities, from the interlacing of its muscular fibres, and he naturally says that they appear ill calculated for conveying a fluid through them. There is an attraction between fluids and solids, he might observe, and this attraction is increased by the extension of the surfaces of the pillars and cords which he sees in the interior of the heart.

We must remind him that the blood is coming back from the body, having performed very different offices in different parts, and has parted with different properties in the several organs it has supplied. There is in that stream of blood which enters through the vein a new supply of fluid which has come by digestion, the material for making fresh blood, as well as that which has run the circle. These two fluids must be thoroughly mixed together, and, no doubt, this is one of the offices provided for by the intricacy of the interior of the heart.

Again, looking to the recesses of the cavities formed between the fleshy columns, and behind the valves, we might suppose that the blood would remain there stagnant. There are cavities or recesses too in the remote parts of the circulating vessels, where we might suspect that the influence of the stream would not be felt, and a stagnation might take place. But there is attraction between the particles of fluids as well as between the fluids and their containing tubes. Let us see then how, in this figure, a stream of water carried through a cistern of water will, by its friction, draw after it the water in

the cistern, and carry it above its natural level, and over the side of the vessel.



The stream entering the reservoir, A, by the pipe, B, carries with it all the water, C, which stands above the level of its upper surface. By this we see that the stream of blood entering into the heart, even if its cavities were not emptied at each pulse, as some contend they are, would draw out the blood from its recesses, so that no part could remain stagnant, but, on the contrary, all would be carried in eddies round the irregularities until they took the direction of the great artery, in which they would be perfectly combined.

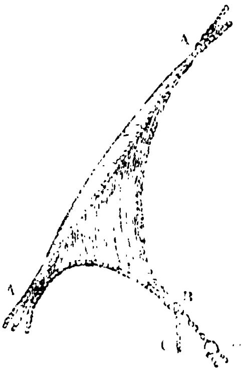
The next thing to be noticed partakes of the nature of a mechanical provision—we mean the action of the valves.

We must here remark, that the opening into the ventricle is very different from that which leads out of it—the latter being much smaller. Medical writers describe this as if it were nothing to them, and a mere accident. But it must be recollected, that a stream of water entering a reservoir, is in a very different condition from that which is going out of it; it is on this principle that the mouths (*ostia* is the anatomical term) of the ventricle are differently formed, and it is this difference which makes the structure of the valves which guard those passages so dissimilar and so appropriate. Without attention to this, we should follow our medical authorities, and call this variety in the mechanical adaptation a mere playfulness

in nature. It is more agreeable to us, to see a precision of design visible at the first step of this inquiry.

The valves of the heart are regular flood-gates which close the openings against the retrograde motions of the blood. They are not all of the same mechanical construction; and their difference deserves the reader's attention as proving design in this hydraulic machinery.

The valve which we have first to describe closes the opening betwixt the auricle or sinus and the ventricle, and prevents the action of the ventricle propelling the blood back again into the auricle.

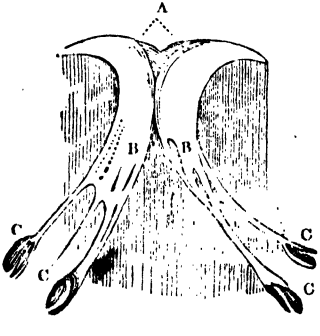


It is a web or membrane, resembling a sail, when bagged by the wind. The blood catches the margin of this membrane, and distends it as the wind does the stay-sail, or jib, of a vessel, which it much resembles, being triangular and pointed. There are three of these membranes, and the valve is called *tricuspid*, or three-pointed. Three membranes then, of this kind, combining and being floated back upon the mouth of the opening, effectually close it.

The illustration of the action of these valves by a sail is so perfect, that if the reader will have patience to

attend to those little contrivances which the mariner finds necessary for strengthening his canvass, and giving to it the full influence of the wind, he will have an accurate idea of the adjustment of these floating valves.

To carry on the comparison—one edge of the stay-sail is extended upon the stay A A, and tied to it by *hanks*. The edges of the sails called the *leeches* have a *bolt-rope* run along them; and on the edge where it is attached the canvass is strengthened by being hemmed down or tabled. In the same way as the foot of the sail, or lower margin, is strengthened with the bolt-rope, just so are the valves strengthened at their edges and their corners. Where the two ropes join in the loose corner of the sail, they form a clue—a loop to which tackle is attached; the valve has such a corner, so strengthened, and has a cord attached. The corners of the sail are strengthened by additional portions of canvass called patches; so are the valves strengthened where their tendons are infixed. To the corner or clue, B, ropes are attached which are called the *sheets*, C C. These being drawn tight, spread out the foot of the sail to one side or the other, according to the direction of the wind, and the tack the ship is on; the valves have also their tackle; and, in short, we shall find a resemblance to all the parts of a sail in the valves of the heart.



One edge of the triangular valve is tied to the margin of the opening, as one of the leeches of the sail is attached to the stay; the opposite corner is loose, and floats, as the sail does in tacking, until the blood, bearing against it as the wind bears against the sail, bags and distends it; the corner is then held down by tendons, for there are cords attached to the corner of the valve, as well as to the corner of the sail. These the anatomist calls *cordæ tendineæ*, B B, which in their office have an exact resemblance to the ropes called the sheets of the sail. They are delicate tendons attached to the margin of the valve, and they prevent the margin from being carried back into the auricle.

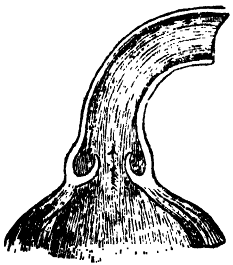
Here we find a very beautiful muscular apparatus which is necessary to the perfect adjustment of these cords. The cords are attached to small muscles called *columnæ carneæ*, C C, or fleshy columns, which at their other extremities are incorporated with the muscular wall of the ventricle itself. The use of these muscles is now to be explained. Had the tendinous cords of the valves been tied to the inside of the wall of the ventricle, without the intervention of these muscles, as the walls of the cavity approach each other during their contraction, the tendinous cords would have been let loose, and the margins of the valves carried back into the auricle. But by the intervention of these muscles, they are pulled upon and shortened in proportion as the sides of the cavity approach each other.

On the whole, then, we perceive that this apparatus, which is as intricate as the rigging of a ship, consists of a variety of fleshy columns and cords, many of which, in fact, run across the cavity of the ventricle.

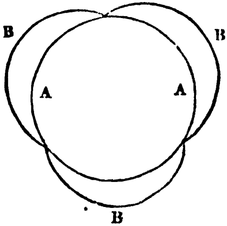
We are about to exhibit another form of a valve, much simpler, and yet we are bound to believe equally effectual: which tends to support the opinion expressed above, that besides preventing the retrograde motion of the blood, this intricate apparatus of the ventricle is intended more effectually to agitate and to mix the different streams.

At the root or origin of the great artery, called the

Aorta, there is a firm ring to which the valves now to be described are attached. The necessity of this will appear evident, since, if the ring could be stretched by the force of the heart's action, the valves or flood-gates would not be sufficient to close the passage; their conjoined diameters would not equal that of the artery which they have to close. These valves are three in number: they are little half-moon-shaped bags of thin membrane, which are thrown up by the blood passing out from the ventricle, but by the slightest retrograde movement of the blood their margins are caught, and then, being distended or bagged, they fall together, and close the passage. There are some curious little adjuncts to these valves, which ought to be explained, as showing the accuracy of the mechanical provision.

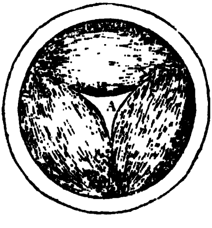


When the margin of the valve is thrown up by the blood passing out of the heart, it is not permitted to touch or fall flat upon the side of the artery, for if it did, it would not be readily caught up by the blood that flows back; there is therefore a little dilatation of the coats of the artery behind each valve by which, although the margins of the valve be distended to the full circle, they never cling to the coats. These valves, then, are never permitted to fall against the coats of the artery, and therefore they are always prepared to receive the motion of the refluent blood.



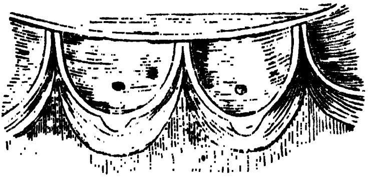
Let this figure represent a transverse section of the root of the aorta, A A, the inner circle is the margin of the three valves thrown up to let the blood pass. B B B are three semicircular bags formed by the dilatation of the coats of the artery at this part, receding from the margin of each of the valves—consequently, in such a manner as to leave a space between the valves and the sides of the vessel.

To strengthen the valves, a tendon runs along their margin like the bolt-rope or foot-rope along the edge of a sail, and these ligaments are attached to the side of the artery, and give the valve great strength.



These valves, we have said, are semilunar; consequently, when they fall together, there must be a space, A, left between them. If we put the points of the thumb, fore and middle fingers, together, there is a triangular space left between them; such a space be-

tween the convexities of the three valves would be a defect.



The artery open, and the semi-lunar valves, like little bags, attached to the inside.

Three little bodies like tongues are therefore attached to the middle of the margin of each valve, and these falling together, when the valve is shut down, perfect the septum and prevent a drop of blood passing backwards.

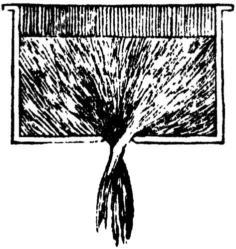
The valves have no power of accelerating the motion of the blood; they only prevent its retrograde motion, and cause the whole power of the heart to be employed in directing the blood forwards in the course of the circulation. But when they are ruptured, when the valve first described is rent, or the cordæ tendineæ are broken, then the membrane, which we have said is like a sail, is carried back from the second into the first cavity. It is like the sail torn from the sheets and flying out before the wind: the effect is terrible: the pulse of the heart, the whole force of which should be given to carry the blood forwards in the arteries, has half its force directed backwards upon the veins.

In the same manner the semilunar valves in the root of the aorta may have their margins torn. We have described the margin of these valves to be strengthened by a tendon or cord run along their edge, like the rope which is sewed to the edge of a sail. There is an obvious intention in strengthening the valve here; but when textures of this kind become impaired in the human frame, this may give way and be torn, and then

the reaction of the artery, when the heart has given its stroke, is lost; for, instead of impelling the blood forwards, the blood runs backwards into the heart. The effect of these accidents is extreme debility of circulation, with symptoms varied according as the defect falls on the circulation through the lungs or through the body—that is, whether on the right or the left heart of man. But such accidents are rare, and never take place until disease has impaired he strength of what we may call the tackle of the valve.

The next remark is founded more directly on the hydraulic principle.

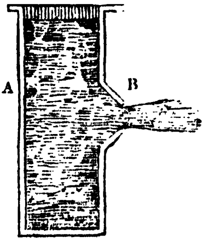
This ring and these valves at the beginning of the great artery imply a certain constriction, or diminution of the tube at this part; and we have now to show that such a contraction of the tube at this precise part does not diminish the diameter of the column of blood. This appears an inconsistency; but if a stream of water flow from a cistern, through a hole in that cistern, the column of water will be diminished at a certain point of its exit.



The water flowing through the bottom of the cistern may be represented by converging lines; and their united forces impelling the stream forward, contract it just beyond the exit—the *Vena Contracta.* Nature, taking advantage of this law, has constructed the narrow ring which we have shown is necessary to the accurate adjust-

ment of the valve, at the precise part where the blood, issuing from the cavity of the ventricle, is necessarily contracted to the smallest space. The column of blood would be contracted at this point, even if there were no coats of the artery to confine it there.

We had thought of this as a thing indicated by reasoning, but we find that an appropriate experiment has been made which proves it.



A being the side of a reservoir, and B a short tube giving issue to the water, it will deliver as much water by this conical constructed mouth, as if the tube were of equal diameter with the hole in the reservoir. The reader will perceive how satisfactorily this indicates what is designed by the difference in the size of the mouth of the ventricle which gives entrance, and that which gives issue to the blood.

With a view to explain the motion of fluids in tubes, and finally the motion of the blood in the blood-vessels, let us consider what takes place in the motion of the column of water which is not contained in a tube.

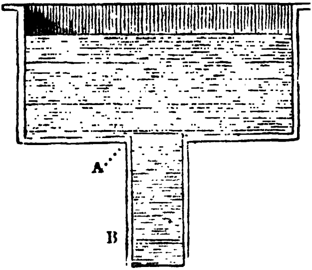
When water is poured out, and descends in an uninterrupted stream, the column contracts as it descends, until it has acquired such a velocity, that the atmosphere opposes it and scatters it; we do not mean the contraction illustrated by the figure in p. 239, but that gradual diminution of the diameter of the stream, owing to the height from which it falls. We apprehend that this is on the principle,

that falling bodies are accelerated as the square root of the height from which they fall. The stream being more rapid at its lower part, is necessarily smaller in diameter, until, having acquired considerable velocity, the resistance of the atmosphere separates its filaments, and it becomes broader again.

A very different appearance is presented in a jet d'eau; here the ascending stream widens as it ascends. The explanation of this we conceive to be, that the fluid is retarded as it mounts, and that the stream propelled from below is forced between the filaments* of the

* Those who treat of hydraulics divide a column of water into ideal lesser columns, which they call filaments, with a very different meaning from the fibres of the anatomist.

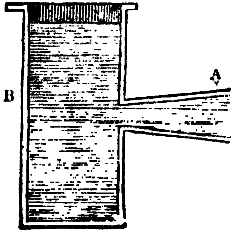
column above, and disperses them, so as to give the column a conical form.



This reservoir will be emptied more rapidly if, instead of a hole in the bottom at A, the water be discharged by a tube, A B, of the diameter of the hole.—Here the column of water being perpendicular, it will be accelerated at its lower part; but instead of diminishing its diameter, as it would do, if not confined by a tube, it will draw an additional volume of water down, and accelerate the discharge.

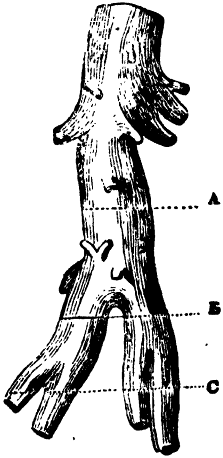
It will be very different if the force be altogether from behind, as when water is propelled into a horizontal tube.

The tube A being conical, will discharge more fluid from the reservoir B than if it had been of equal length,



and its diameter throughout the same as at its commencement. Because, as it appears to us, the weight of the descending column being the force, and this operating as a *vis a tergo*, it is like the water propelled from the jet d'eau, and the gradual expansion of the tube permits the stream from behind to force itself between the filaments, and disperses them without producing that pressure on the sides of the tube which must take place where it is of uniform calibre. These principles will give great interest to the following fact.

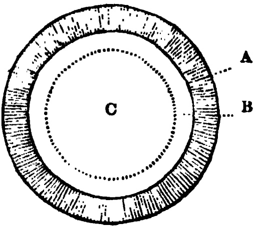
The celebrated John Hunter took great pains to prove that the artery had its diameter enlarged as it proceeded from the heart, and that the areas of the branches of an artery were greater than the diameter of the parent trunk.



That is to say, the section of the trunk at A was not so great as the two sections at B, taken together; that the two sections at B taken together, were not so great as

the four sections at C; that the conjoined diameters, therefore, of the branches of an artery were greater than the diameters of the artery itself. This fact has been sometimes expressed by saying that the artery was a cone with its apex in the heart.

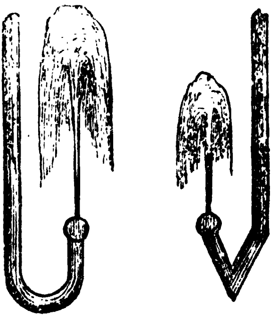
When we stand by a rapid river, we can perceive that the surface of it is not level. The stream is rapid in the middle, and there the water is highest. The friction of the water against the bottom and the sides retards the stream, whilst the greater velocity of the current in the centre draws the water to it, which is the reason of its elevation there.



For the same reason, if an engineer estimate the quantity of fluid to be delivered through a tube without estimating the friction of the sides, he will be disappointed in the result of his calculation; for, as the water of the river is delayed by the bottom and sides, so is the fluid in the tube retarded by the attraction or friction between the water and the tube. And, if we can imagine a section representing the tube and the flowing water, A will be the solid tube, B the water retarded or arrested by the friction against the tube, and the space C, within the inner circle, would represent that part of the stream which is in uninterrupted flow. The engineer will therefore lay a tube larger than would be necessary, were there neither attraction nor friction between the solid and fluid. It must further appear that the smaller the calibre of the tube, the surface of attraction or friction will be propor-

tionally greater. Does not this explain the anatomical fact which we have been contemplating, that the area of the smaller branches is comparatively larger than the trunk from which they are derived?

Two beneficial effects result from this; for we must observe that the blood-vessels of the body are reservoirs as well as conduit pipes. A man of middling stature has thirty-three pounds of blood in his circulating vessels: if the vessels did not enlarge as they receded from the heart, there would be no place for the deposit of this great quantity of blood. The advantages, then, of this particular form are, first, that a quantity of blood necessary to the economy is contained within the vessels; and, secondly, that the blood is more easily urged forwards by the action of the heart. The reader will not now be surprised in learning that a pipe of a conical form, that is, enlarging as it proceeds, gives the least interruption to the flow of water from a reservoir.



Water flowing in a tube will be retarded by any sudden angle in the tube. If the ajutage of a jet d'eau have not a gentle and uniform sweep where it is turned, the jet of water will not reach the height which it ought to do by calculation of the height of the reservoir of water from which it descends—it will go higher from the tube A than

from B. This circumstance explains the uniform and parabolic curve which the great artery of the body takes in first ascending from the heart. It explains also why the branches of the great artery go off at different angles, according to their distance from the heart, or, in other words, why they pass off at smaller angles with the stream the farther the artery recedes from the heart.

In the distribution of water-pipes, it is very necessary to attend to the angle at which the small pipe is attached to the greater one, not only because a pipe being bent abruptly causes loss of motion from the impulse of the fluid against the side, but also from another well-known law of hydraulics.

If a pipe be fixed into another so as to join it at an angle contrary to the direction of the stream, the discharge into that lateral branch from the larger tube will not only be much smaller than we might estimate by the diameters of the tubes, but, in certain circumstances, it will discharge nothing at all; nay, on the contrary, the water would be drawn from the lesser tube into the greater, until the lesser tube be emptied, and air be sucked in.

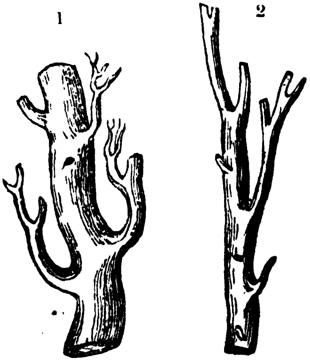
Bernouilli found that when a small tube B was inserted into the side of a horizontal conical pipe A, in which the water was flowing towards the wider end C, not only none of the water escaped through the small tube, but the water from a vessel placed at a considerable distance below was drawn up through the tube B into the pipe A. (See fig. at p. 126.)

With these facts before us, we turn with interest to what the anatomist too often contemplates with unconcern, we mean the different curves in the branching of the arteries and veins; for by this law of hydraulics the junction of the branches and trunks of the arteries and veins ought to be different, as the one vessel, the artery, carries the blood out from the heart, that is, from trunk to branch—and the other vessel, the vein, carries it in the opposite direction towards the heart, or from branch to trunk.

And in matter of fact, their branchings are very dif-

ferent, and characteristic of the vessels. We have heard a teacher of anatomy express himself in this manner: "The arteries are active and powerful vessels, which carry the arterial blood out from the heart—and they receive the forcible impetus of the heart. When they are wounded, the man bleeds to death;—therefore, nature conveys these vessels into the recesses of the body, taking advantage of every protecting bone—conveying them so that the bones and the muscles protect them. There are no irregularities in their course, and their branches go off at a determined angle, and never irregularly; but the veins," he would continue, "are vessels of less importance—they convey the blood back to the heart, with a languid motion, and if they are wounded the blood flows with so diminished a force that you can stop it with the pressure of your finger; accordingly, nature is more negligent of them, they run in all their courses irregularly—some deep, some superficially; and their branches join their trunks with awkward irregular curves and elbows."

1 2



This is in good feeling, and is in part true; but it contains somewhat of the error which runs through most

anatomical discourses, of supposing things are irregular, as if the objects in view were inartificially and imperfectly attained. From inattention to the hydraulic principle, he seemed not to have considered that the connection of trunk and branch must vary according to the direction of the stream,-- that the direction of the branch, which is adapted to lead the stream from the trunk into the branch, must be altered when the design is to convey the fluid from the branch into the trunk.

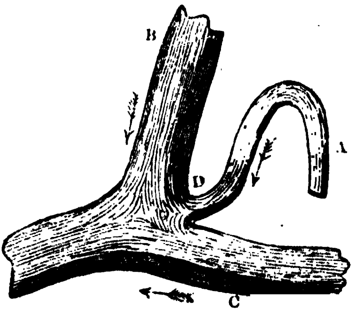
The reader will now understand, that the branch of the artery (No. 1, p. 247) gently diverges from the direction of the stream, while the branch of the vein, in No. 2, enters abruptly and at right angles. We may illustrate this by observing, that if we could suppose the vein substituted for the artery, and the artery for the vein--if the vein carried the blood outwards, instead of towards the heart, and the artery conveyed the blood back to the heart, the blood could not run in the circle; it would be retarded, and congestion would take place, somewhere in its course.

We have seen by the demonstration above, that if the veins of the human body were rigid tubes, and if a hole were made in their sides, air might be drawn in, instead of blood flowing out. This is a matter of vital consequence, for if a very little air be blown into the veins of an animal, it dies in an instant, and there is no suffering nor struggle, nor any stage of transition, so immediately does the stillness of death take possession of every part of the frame.

In conversation with Napoleon's celebrated surgeon, Baron Larrey, on the case of a young man wounded in the neck, he said he had no hesitation in declaring the cause of death to be, air drawn in by the veins of the neck, and he quoted instances occurring at the battle of Wagram. These circumstances greatly increase the interest of an experiment made by Dr. Barry, who found that on introducing a tube into the vein of the neck, and placing the other end of the tube in a vessel of water, the water rose during inspiration. The difficulty of explaining this arises from those veins being membranous tubes,

and consequently compressible; but in the act of inspiration, not only are the ribs and breast-bone raised, but the muscles of the neck attached to the collar-bone rise from the veins of the neck. By this means, instead of suffering the compression of the incumbent parts, the atmospheric pressure is taken off the veins; they are brought to the condition of rigid tubes; and the principles of hydraulics explain the rest. Thus the figure given at p. 128 is a reservoir emptied by a perpendicular tube, into which a smaller tube is inserted. The water descending by the larger tube, will draw the water up through the lesser tube, so as to empty the glass in which its lower end is immersed.

We shall here give an example of the manner in which the trunk of the absorbent system joins the venous system, a circumstance which has not escaped the notice of anatomists. The absorbing or lymphatic system consists of a set of vessels different from arteries and veins, which imbibe by a sort of capillary attraction at their extremities, and convey their fluids towards the centre, without any such impulse as the proper blood-vessels receive from the heart. The stream in the trunk of this vessel has no force to impel it into the stream of blood in the veins; it enters, therefore, in this manner.



A is the trunk of this system, called the thoracic duct;

B is the great jugular vein descending from the head, and C the great vein coming from the arm. These veins join at an angle, and the streams from them, in the direction of the arrows, leave a point between them at D, where there is no pressure. If two tubes enter into a larger tube obliquely, and the water be flowing from the lesser tubes into the greater one, and if a hole be bored at the angle of their union, the water will not escape at that hole. Therefore the fluid from the thoracic duct A meets with no impediment at the point D; when entered, we have seen, by a former diagram, how the attraction of the more forcible stream will draw the contiguous fluid after it. By this contrivance, if we may use the word, the fluid in the absorbing system finds access to the red blood, and is carried into the heart.

We might continue this subject by considering the influence of respiration on the circulation; but we shall pursue the inquiry into the hydraulic principles, as applicable to the circulation, independently of pneumatics.

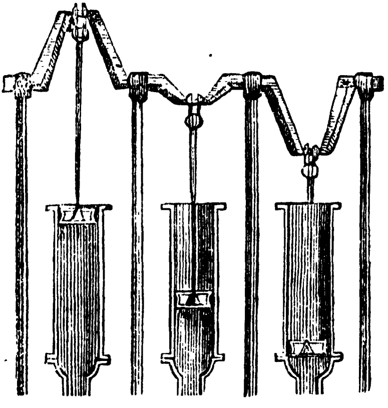
The law of inertia, which is of easy comprehension as it regards solids, is also applicable to fluids; it is easier to keep a column of water in a pipe in motion, than to put it into motion from a state of rest.

In a forcing pump, when after each movement of the piston the column of water becomes stationary, power is unnecessarily lost by bringing the column of water, which is in this state of rest, again into motion; but if a second blow of the engine be given to the column of water whilst it is yet moving, it is found to be more easily pressed forward, and no part of the force is lost in urging it from a state of rest into motion. This is evinced in the contrivances of the engineer. He employs two forcing pumps instead of one, and he so applies his lever as to operate alternately on the one and the other; to the end that the water in the pipe may be kept in uninterrupted motion. Let us apply this principle to the circulation of the blood.

If the heart were the only power forcing on the blood, there would be a cessation of motion after each pulse of the heart, and therefore a great part of its power would

be lost. This explains why there is a power in the artery as well as in the heart. The artery being muscular, seconds the operations of the heart; its muscularity, and the muscularity of the heart, are powers exercised alternately, and which, acting like the double stroke of the engine, permit no interval to the motion of the column of blood. If the heart had to act upon a column of blood at rest, not only much of its force would be unnecessarily exhausted, but it would be excited to propel an inert body, and a dangerous shock would arise from the resistance.

If we pursue this subject, and inquire what is essential to such a hydraulic machine as we are contemplating, we shall perceive that the engineer meets with a difficulty in adjusting the powers of his two pumps, and finds an interval, or pause, in the application of their forces.



To obviate this he makes three cylinders, the pistons of which are moved by a crank, which so orders the descent of the pistons as to fill up this interval, so that one

of the pistons shall be always descending; and these pumps propelling the water into a common tube, there is no interval to the motion of the fluid through it.

By this example we are led to look for something corresponding in the machinery of the circulation. We find no third active power, however; yet we find a quality in the blood-vessels which answers the purpose much better. But to comprehend this, we must observe that the engineer has a more admirable contrivance than this of a third pump to adjust the action of the other two.

He confines a body of air which, by its elasticity, performs the office. The pipes of two forcing pumps are carried into the reservoir B; they convey the water up to C, by which time the air is compressed, and its elasticity thereby increased; that elasticity is exerted without interval, and, acting on the water C, propels it into the tube D uninterruptedly. (See figure at p. 132.)

Just such an elastic property is possessed by the arteries. The great artery which goes out from the heart, as we have had repeated occasion to observe, makes a sweeping curve; it is capacious, and is the most perfectly elastic of anything in nature. Here then we have the three powers which the engineer finds necessary to employ. We have the alternate action of the heart and artery, and we have an elasticity which, though passive, is essential, both to the uniform flow of the blood, by filling up the interval in the action of the two powers, and to the safety of the engine itself; for without this elasticity there would be such a jar as must speedily destroy the mechanism.*

There is nothing more admirable than the influence of this elastic power; it is greatest in the coats of the artery near the heart, weaker in the coats of that artery

* But does the blood flow uniformly? Not precisely so in the arteries, since the stroke of the heart is more powerful, or rather more concentrated, than that of the arteries. During the contraction of the ventricle of the heart the artery is dilated, but it is never emptied; and the flow of the blood forwards in the course of the circulation is not for an instant interrupted.

as it recedes from the heart; this very evidently declares its use: but we shall take a more sufficient proof, although an unhappy one.

As life advances, the arterial system loses much of its elasticity, and becomes rigid. This is so common an occurrence that we can no more call it a disease than the stiffened joints of an old man; it is the forerunner or the accompaniment of the decline of life. But this sometimes takes place too early in life, and to an extreme degree; and from its effects we must call it morbid; for it not unfrequently happens that the muscular power of the heart being still entire and vigorous, the arteries can no longer sustain it. They are not now endowed with that power which, yielding to the heart's action, resists, and recoils the more it yields—which takes off all sudden shock, and which in yielding wastes no power, since on its recoil it gives as much force to the acceleration of the blood as was lost of the heart's action. The artery then becoming rigid, yields indeed to the heart's impulse, but has no recoil. It is permanently dilated or enlarged. It is now called aneurismal. A stronger impulse from the heart, excited by inordinate action or passion, chips and bursts the now rigid coats of the artery. If the breach be sudden, it is death; if it be gradual, a pouch forms—a true aneurism. And now we have the proof we require; for this bag coming to press upon the solid bones, they are destroyed. That action of the heart which was so lightly and so easily borne whilst the vessels were elastic, now beating upon a solid structure, in a short time destroys it. Thus we are led to a more accurate knowledge of the fine adjustment of the active and resisting properties in the circulating vessels during youth and health, by what takes place on a very slight derangement of those powers.

CHAPTER II.

THE ILLUSTRATIONS FROM MECHANICS MAY BE CARRIED TOO FAR. PECULIAR PROPERTIES OF LIFE IN THE BODY. THEY DIFFER IN QUALITY. THEY HAVE AN ADJUSTMENT TO EACH OTHER, MORE ADMIRABLE THAN THE MECHANICAL CONNEXION.

WE are the more desirous of entering upon this subject, that we may prevent the reader from founding a false conclusion upon the very mode in which we have hitherto proceeded, that of showing design in every part of the animal structure by taking our illustrations from the mechanism of the body.

When we have admired the connections of the several parts, or organs, thus made manifest by comparison with machinery, we may go too far, and say, that the material structure and mechanical relation are to be found in still greater minuteness and perfection in the finer textures of the body, proceed to call this organization, and erroneously conclude, that out of organization comes Life. The very term organization misleads; yet it implies something constructed, in which one part co-operates with another; but nothing more. Taking the body as a whole, there are undoubtedly instances of such co-operation, but it is in vain to seek the explanation of life from this; since life exists in simple and uniform substances, where there is neither construction nor relation.

Now, although there are mechanical construction and relation, as we have seen, in bones, muscles, and tendons, the phenomena of the body result from a dependence established among the living properties, not the

mechanical. The highest medical authorities have seen reason to conclude that life is an endowment, not resulting from organization or construction, but, on the contrary, producing it; in other words, that the living principle attracts the new matter, arranges it, and, in order to its continuance and perfection, alters it, and effects a continual revolution in it. For there is nothing more curious than the uninterrupted and rapid change of the material of the animal body, from the first pulse of life to the last breath that is drawn; of which we shall give abundant proofs before we close this inquiry.

In first approaching the subject we are blinded by familiar occurrences, and cannot comprehend all the links by which the visible phenomena of the living body are produced. Probably most of our readers believe motion to be a necessary consequence of life, and the very proof of its presence. The peasant stirs up an animal with his staff, and if it does not move he is satisfied that it is dead; and such is the experience of mankind. We do not reflect that many different qualities of the living powers must be exercised before sensibility is shown in its visible sign, the motion of the creature. It is not necessary that the parts shall lock into each other like the cogs of wheels;—the connections established are of a different kind altogether. Each part possesses a property of life entirely distinct from the other, and this property of life may exist in the individual part (for a time at least) without that co-operation of the whole which is necessary for the motions of the animal.

This quality of life is, in one respect, like gravitation in matter; that is, when the mass is broken into parts, each division has its proportion of the endowment, and so the separated parts of a living creature possess life. But here the resemblance ceases; gravitation is the same quality in every part, and uniform in its effects, whilst the life is exhibited by qualities differing in every part of the animal body. Did these parts possess qualities exactly similar, they would remain at rest, and though combined, they would not influence each other.

It is the different powers brought into combination that produce the motion of the whole animal.

If a man fall into the water, and is dragged out motionless, and has ceased to breathe, each part of his body may still possess its property of life. Although the combinations have been destroyed, he may be revived by exciting action in some part of his system. Life still remains in brain, and nerves, and heart, and arteries, and in the muscles, which should enable him to breathe; but the mutual influence, the bond of their united operations, is broken. We may take the analogy of a machine, and say that the wheels are stopped; but this is in fact a very different thing; it is the operation of the living influence that is stopped; for we repeat that nature (by which, of course, is always to be understood the Author of Nature) has combined the organs not mechanically, but by properties of life.

Artificial respiration draws after it the action of the heart, because the sensibility of the heart is made respondent to the lungs. Pulsation of the heart, excited by the motion of the lungs, is followed by the action of the arteries; these organs in operation drive the blood through the frame, and by the circulation the susceptibility of each part to impression, which had been weakened, is restored. Action and reaction are re-established; but these actions are not like those of a machine, they are living properties; sensibility in one part, contractility in another; and after a variety of these internal sensibilities have been for some time in operation, the man gives outward token of recovery.

So a person recovering from fainting, after sobbing and irregular breathing, has the respiration renewed; in succession other parts recover their sensibility and resume their places in the circle of relations; the skin is capable of being stimulated, and the limbs are capable of motion; the eyelids are opened; by and by the nerve of the eye is sensible to light, and the nerve of the ear to sound; and, finally, the faculties of the mind are roused, and its control over the body re-established.

The whole separate endowments of life in the different parts resume their offices;—the last in the train; only the property of the muscle to contract is alone observed by the uninformed, and voluntary motion is the token of entire restoration.

We can imagine a half-learned person to act very foolishly in the attempt to restore the apparently drowned. He has been told that we draw in vital air, and breathe out what is unfit to support life; he imagines that it can be of no use to distend the lungs of the drowning person with his own breath, and precious time is lost. Whereas, the mere distension of the chest, that is, of the lungs, followed by the compression of the chest, and again by the distension, and so on alternately, is the *play of the lungs*, which by sympathy draws the heart into action, and in succession all the vital organs. This is not what chemistry teaches; chemistry shows us that the vital air influences the blood; and it is true that the blood, being refreshed or impregnated with the vital air, renews the properties of life. But this effect on the blood could never take place unless there were some previous consent or sympathy, putting the organs into operation. We repeat that the consent of organs is not the effect of mechanical adaptation, or of chemical action, but of relation established among the vital properties.

If a man be struck by lightning, he has not merely the vital operation of respiration stopped, as in the case of the drowning man, in whom every organ continues to possess its property of life; he is not like a man struck on the head, where one vital organ is so disturbed that the circle of vital actions is broken; in this instance the electric fire passes through every fibre and every organ; all the qualities of life, whether residing in the brain, nerve, or muscle, are instantaneously destroyed; and the moment of death is the commencement of dissolution.

Mr. John Hunter illustrated this somewhat familiarly. If you bruise the head of an eel, its body writhes; but if it be taken by the tail, and struck on the flag-stone, so that every part of its body receives the shock, then

all the parts are killed, and it remains motionless. When an animal is killed by that violence which injures one important organ, the property of life remains for a certain time in every part; those parts have no correspondence, and there is no outward token of life; but the vital principle is still capable of exhibiting one of its most important properties; it arrests the operation of those chemical affinities which belong to dead matter.

Thus the reader perceives, that, although he be led on to comprehend the design or intention manifested in the structure of the body by mechanical instances or comparisons, it is when we contemplate the influence of the living principle, that we have a higher conviction of the Omnipotence which has formed every creature, and every part of each creature, with that appropriate endowment of life which suits it to act its part in the general system.

We must learn to distinguish between the death of the animal and the death of the parts of the animal—between apparent death and dissolution, or the separation of that quality which distinguishes living matter.

Viewing the subject generally, as Mr. Hunter said, there are not two kinds of matter, but two conditions of matter. It is at one moment forming beautiful combinations, as in the flower, through the principle of life, and, at another, it is cast away as noxious, undergoing changes by decomposition, from chemical processes solely. The want of combination in the whole animal body exhibits apparent death. The loss of life in all the parts of an animal body is absolute death, and the material becomes subjected to the influence of the chemical affinities instead of being urged into motion by life.

The jackstone produces motion in one part of a machine; that, varied by mechanical influence, is communicated to a second; from the teeth of one wheel it is communicated to the corresponding leaves of the pinions, and from the pinions to the fusees. But what a base notion it is to suppose that the mere property of weight in the jackstone is like the influence of life!

The weight is the power, in the language of mechani-

cians; but it does not reside in the parts of a machine, nor does it exhibit different qualifications in these parts. Separate them, and they are nothing. On the contrary, no one part of an animal body is in this manner dependent on another for its property of life. The property is inherent in the part itself, and the wonderful thing is that each property in the several organs corresponds with the others, so as to form a circle of vital operations. There is no transmission of power, in all this, from part to part —no train of connection to be traced as from the jack-stone, or the spring, along the parts of the machine. There is, therefore, in truth, no resemblance between machinery and the influences in operation in a living body. What is to be admired in a living body is not merely the adaptation of bones, muscles, and tendons, forming a mechanical apparatus, but rather the different qualities which life bestows upon different parts; these qualities put the parts into relation each according to its place in the circle of the economy; and among innumerable properties of life in the individual parts, produce that perfect co-operation as if one principle only actuated the whole.

When a person moves under the direction of the will, nothing can be more simple to our understanding, because we do not attempt to trace the links, far less to estimate the powers in the several parts influenced during this familiar action. But if there be the slightest diminution of sensibility of one nerve so that it shall not transmit sensation; or if there be any disturbance which retards in the least degree the transmission of the will along another appropriate nerve; if the muscle be benumbed, or have lost its irritability; if the action of the blood-vessels has been either diminished or increased beyond their ordinary course, either in the organs of sense, the brain, or nerves; we are appalled by the consequences. The impressions of things are not felt; the senses are unexercised; the limbs remain inactive; one half, or the whole, of the body is a load, as if there were a living being in a dead body—a body whose parts refuse their office, appearing dead, though they are not so. The correspond-

ence of their living qualities has alone been disturbed, the movement which results from the whole is stopped, and there is apparent death.

What confusion then must be engendered in the minds of those who would confound the phenomena of life, as presented in the entire framework of the body, with those separate qualities of life which, residing in the several parts, must enter into combination for the motion of the whole! The next step of this unphilosophical manner of treating the subject, is to make the organization the source of the living property,—as if any combination of organs could produce life,—as if those organs could have motion without the distinct endowments of life in their separate parts,—as if they co-operated mechanically, and not from the correspondence among their living properties. Those who thus reason mean to say that parts are made so finely as to move of themselves, one part propelling another, and the motion of the whole producing life. It is quite clear that this confusion of ideas arises from contemplating the phenomena of the perfect animal, in which all intermediate influences are confounded. On the other hand we present this proposition.

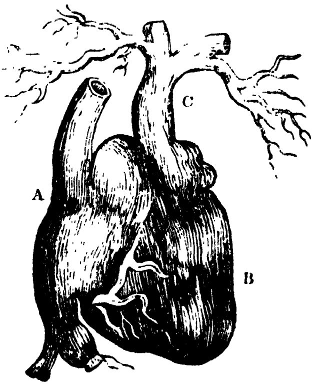
The several *simple* substances of a living body have each an endowment of life bestowed upon them. Let us take the obvious qualities, of sensibility—the power of transmission — and the power of motion; each of which is appropriate to a particular substance. When these qualities are put in relation, impressions may produce motion, and thus there are three distinct properties of life brought into operation. Where is the organization or construction here? Without those living endowments these parts would be inoperative, in whatever juxtaposition placed. The mechanical construction of the body is one thing: and we are able to admire it, because it can be illustrated by comparison with our own contrivances; the combination of living properties is another and an entirely different thing.

We here reach the limit of philosophical inquiry. Hitherto all has been flattering to the pride of the creature; but we must now humbly acknowledge the inscrut-

able ways of the Creator; and ceasing to trace the origin of life, more than we do that of gravitation, we should be occupied in observing its laws, not in exploring its source.

We shall take an instance to illustrate the difference betwixt the mechanical connection of parts and their relations through the living properties; and it will, at the same time, show how curiously the living properties and the mechanical properties are made to correspond with each other.

A stream of water is converted into a mechanical power; it fills a cistern, which is attached to a lever; the cistern descends by the weight of water; by its descent a valve is pushed open; the water escapes, and the cistern ascends, and remains so, till the stream flowing into it again, depresses it. Thus the regularity of the supply of water gives regularity of motion to the machine. Compare this with the heart.



We may describe the heart as consisting of two cavities, the one called the *Auricle*, and the other the *Ventricle*. The sinus A receives the blood returning by

the veins, and gradually filling, like a cistern, it becomes so distended, that its muscular power is excited; it contracts, and delivers the blood with a sudden impetus into the second cavity, or the ventricle B; which, in its turn, excited by the distension, contracts, and propels the blood into the artery C. Here the action of the heart is accounted for, by its mechanical distension with the blood: and the regularity of its motions necessarily corresponds with the regularity of the supply. The distension produces action, and the propulsion of the blood from the cavity allows a momentary state of rest, until another volume of the blood excites another pulse.

But we have now to observe, that when this irritability or muscular power was bestowed upon the heart, it was directed by a law entirely different from the irritability, as possessed by other muscles. A property of alternate activity and rest was given to it, quite unlike the contractility of other parts; and accordingly when the heart is empty, when there is no distension of blood at all, the two cavities will continue their alternate action. Nay, if the heart be taken from the animal recently dead, it will continue to act in regular successive pulses, first the one cavity, and then the other, and so on successively for a long time, until the life be quite exhausted. The two cavities will thus continue in alternate action, as if they were employed in the office of propelling the blood, when there is no blood contained within them. It is superfluous to observe, that no such thing could happen in the case of the cistern and lever, were the stream of water to cease running.

Thus we distinguish two things quite different—a mechanical or hydraulic provision, by which these little cisterns, the auricle and ventricle, shall be regularly supplied, and alternately filled and emptied—and the property of contraction in the heart; not a mere property of contraction from irritation, as in the other muscles, but a property far more admirable, since the irritability or power of contraction of the part is ordered with a reference to its office—that it shall contract and relax in regular and rapid succession, and continue its office un-

weariedly through a long life. The living property of the heart exhibits a variety adapted to its office, and a correspondence still more admirable than the mechanical relation.

We are thus particular in distinguishing the mechanical adaptation of parts from the co-operation of the vital influences residing in the several parts; for there are many who will take the illustration from mechanics, and stop their inquiry there, and who entertain a confused notion of the dependence of the life of the body on its mechanism.

Another mistake, which some philosophical inquirers entertain, is to fancy that the principle of life is of a galvanic nature. There is indeed an unwillingness in men to acknowledge that their powers of reason are exhausted, and that they have arrived at an ultimate stage; they would fain set up some contrivance to hide the humiliating truth. Whatever notions have prevailed in the schools at different epochs, of heat, electricity, or galvanism, we find an attempt to explain the phenomena of life by an application of the powers, with which they have been successful in their physical inquiries. Experiments without reason are equally delusive with hypotheses; those who will not give themselves the labour of thought, desire to witness striking phenomena; wonder-struck, they believe that they are engaged in experimental investigation, when their state of mind is little better than idle amazement. A calf's head is made to yawn, or a man cut down from the gallows to move like a figure of cards pulled with strings; the jaws move, and the eyes roll, and this is done by conveying the galvanic shock to the nerves; here it is supposed that nothing less than the principle of life itself can work such wonders, and that galvanism is this principle.

Putting aside the circumstance already stated, of life exhibiting totally different phenomena in union with different parts, is there any point of resemblance between galvanism and life? Does tying the nerve stop the influence of galvanism, as it does the influence of life? Does galvanism course along a cord when it is surrounded

by matter in contact with it of the same nature? Can life pass out of one body into another, like heat, or electricity, or galvanism? Can *they* be contained by a thin membrane? Does life pass equally through all the parts of a moist animal body as one uniform influence, like galvanism?

In no circumstance is there a resemblance, and the whole phenomena resulting from galvanism transmitted through an animal apparently dead, are fairly to be attributed to its being a high stimulus conveyed through the moist animal body, and exciting the powers which remain insulated in the several parts; and in exciting those forces, far from renewing them, it exhausts them altogether.

The uses made of galvanism in the explanation of the living phenomena, should make sensible men very cautious how they carry the legitimate inductions of chemical science into another department. They will not submit to call the irritability or contractility of a muscle an endowment of life, but seek to explain it by organization. They employ the microscope; they find the ultimate fibre to be some thousandth part of an inch in breadth; they see plicæ or folds; they imagine them to be cells into which the fibres are divided; they furnish these cells with two different gases, and explode them by some galvanic influence of the nerves; and the explosion by dilating the cells in one direction, causes the contraction in another. This is the theory of muscular action at the period of the discovery of the gases; and some such idle hypothesis, supposed applicable to the laws of life, accompanies every considerable improvement in chemistry.

In the most modern and the most popular French work on Physiology, by Mons. Richerand, he says, "What appears to me by much the most ingenious opinion, and which carries with it the greatest probability, is that which supposes the contraction of the muscle to depend on the combination of hydrogen, carbon and azote, and other combustible substances which exist in the fleshy fibre, with the oxygen conveyed to them through the arteries." But he adds, as if he had perfected the

theory, "it is also necessary to suppose, that a nervous fluid is directed through the muscle to determine the decomposition, as the electric spark forms water out of two gases."

Such is the chemical theory of muscular motion; it betrays an entire misunderstanding of the phenomena of muscular motion, and of the beautiful provision in every muscle for its appropriate office. The muscles, which are subservient to the organs of sense, differ in their operations altogether from the voluntary muscles of the limbs. The hollow muscles, as they are termed, those which carry down the food, and which carry round the blood in circulation, vary in their time and manner of acting according to their offices; but what conception can he have of such adjustment of powers, who is entertaining himself with a theory, that supposes a sudden explosion to take place in the fibres of the muscle at their time of action? Inductive reasoning, which has carried men to the highest acquirements in physical science, is here laid aside; conjectures totally inconsistent with the phenomena of life are employed in its stead; and the useful philosopher becomes a very indifferent physiologist.

CHAPTER III.

OF SENSIBILITY.

UNDER this head are comprehended, not any sentiment or feeling of the mind, but the sensations of the body.

We form our notions of sensibility from that of the skin; and it is no doubt necessary that we should do so. It is in constant communication with things around us, and affected by their qualities; it affords us information, which corrects the notions received from the other organs of sense, and it excites our attention to preserve our bodies from injury. We are so familiar with the painful effects of injuries upon the surface, that there is nobody who does not imagine that the deeper the injury, the more dreadful the pain. But, on the contrary, it is a well-established fact, that to such irritants as would give the skin pain, the internal parts are totally insensible. And it is equally certain, that though the nerves, the instruments of sensation, are incapable of producing any perception without the brain, yet the brain itself, the part which is the seat of intellect, and to which every impression must be referred before we become conscious of it, is itself as insensible as leather. These considerations show us that sensibility to pain is not a necessary result of life, and they naturally lead to the inquiry for what purpose is sensibility bestowed, and how is it distributed in the body?

We have first to show that the skin has sensibilities exactly suited to the functions it has to perform. Science no doubt informs us, that warmth and cold are only relative degrees of heat; to the skin they are distinct sensations, and excite in different ways both the mind and the bodily functions. Cold braces and animates to exertion, whilst the warmth which is pleasant to us, is genial to all

the operations of the animal economy. Their alternations are the most constant sources of our enjoyment, and at the same time conduce to exertion and to health. All this, however, belongs to the skin exclusively; parts internal, although peculiarly sensible to their proper stimulus, give no indication of sensibility to heat; if there be internal sensations of heat, they are morbid and deceptious. Molten lead would produce pain and death being poured into the interior of the body, but the sensation of burning is a property of the surface only. It is the excess of that particular sensation, which is calculated, like the other endowments of the skin, to suit the medium in which we live, and to force us to the regulation of the temperature necessary to preserve life.

Touch, or the sensibility to bodies pressed upon the skin, is likewise a distinct and appropriate sense. The sensibility of the skin to pricking, cutting, or tearing, is also in curious contrast with the sensibility of the solid internal textures, as bone, cartilage, and ligament. We have arrived at the full comprehension of this subject very slowly. Disagreeable experiments have been made, but the following is as interesting as it was innocently performed. A man who had his finger torn off, so as to hang by the tendon only, came to a pupil of Dr. Hunter. "I shall now see," said the surgeon, "whether this man has any sensibility in his tendon." He laid a cord along the finger, and, blindfolding the patient, cut across the tendon. "Tell me," he asked, "what I have cut across?" "Why, you have cut across the cord, to be sure," was the answer. By such experiments it became very manifest, that bone, gristle, and ligament, were insensible to pricking, cutting, and burning. Were they, therefore, insensible? The reader will answer—Surely, it is a matter proved. But before we finally decide, let us take this into consideration,—that the sensibilities of the body differ in kind as well as in degree; and every part has its peculiar kind, as well as its degree; and every part has its kind of sensibility with reference to its function, and also with reference to its protection from violence. If the membranes between the bones of our

great joints, or the cords which knit the bones, were sensible in the same manner and degree with the skin, we should be incapable of motion, and screwed to our seats; as the man appears to be who has a violent attack of acute rheumatism.

But although these bones and cartilages, or gristles, and ligaments, be not sensible as the skin, or the surface of the eye, they possess that which is suited to their condition, which permits their free use, and yet limits that too free exercise which would be injurious to their textures, or raise inflammation in them. The ligaments and tendons, then, which are insensible to pricking, cutting, and burning, are sensible, nevertheless, to stretching and tearing! It is remarkable that such men as Dr. Hunter and Haller, the luminaries of their science, should have held the opinion that the bone and the membrane which covers it (the *periosteum*), the gristles or cartilages, the ligaments of joints, and the tendons of muscles were insensible parts, and yet be in daily attendance on those who suffer the pain of a sprained ankle, where there are no parts to suffer but those enumerated, and where the pain, excessive in degree, was felt in the instant of the sprain. These considerations explain to us that pain is the safeguard of the body. This capacity of conveying painful impressions to the mind is not given superfluously to all parts; on the contrary the safe exercise and the enjoyment of every part is permitted without alloy, and only the excess restrained.

This subject is finely illustrated by the apparent insensibility of the heart. The observation of the admirable Harvey, the discoverer of the circulation of the blood, is to this effect. A noble youth of the family of Montgomery, from a fall and consequent abscess on the side of the chest, had the interior marvellously exposed, so that after his cure, on his return from his travels, the heart and lungs were still visible and could be handled; which when it was communicated to Charles I., he expressed a desire that Harvey should be permitted to see the youth and examine his heart. "When," says Harvey, "I had paid my respects to this young nobleman,

and conveyed to him the king's request, he made no concealment, but exposed the left side of his breast, when I saw a cavity into which I could introduce my fingers and thumb; astonished with the novelty, again and again I explored the wound, and first marvelling at the extraordinary nature of the cure, I set about the examination of the heart. Taking it in one hand and placing the finger of the other on the pulse at the wrist, I satisfied myself that it was indeed the heart which I grasped. I then brought him to the king, that he might behold and touch so extraordinary a thing, and that he might perceive, as I did, that unless when we touched the outer skin, or when he saw our fingers in the cavity, this young nobleman knew not that we touched the heart!" Other observations confirm this great authority, and the heart is declared insensible. And yet the opinions of mankind must not be lightly condemned. Not only does every emotion of the mind affect the heart, but every change in the condition of the body is attended with a corresponding change in the heart: motion during health—the influence of disease—every passing thought—will influence it. Here is the distinction manifested. The sensibility of the skin is for a purpose, and so is the sensibility of the heart. Whilst the skin informs us of the qualities of the external world and guards us against injury from without, the heart, insensible to touch, is yet alive to every variation in the constitutional powers, and subject to change from every internal influence.

There is in the several organs of the body, as it were, a distinct life; that is, they possess sensibility, the grand endowment of life, necessary to their condition and adapted to their appropriate stimulus. The impressions made upon them will sometimes rouse them into activity, or call muscles into action which are necessary to their functions or for their protection; and this oftentimes without reference to the mind at all, and consequently without our consciousness.

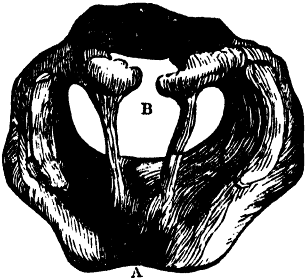
Perhaps we have the most agreeable example of this in the eye. That organ has been selected, in the Preliminary Discourse of the Objects and Pleasures of

Science, as showing how mechanical advantage is taken in the arrangement of the muscles to produce velocity of movement in guarding the eye. But this fine mechanism would be lost if the excitement depended on our will,—if there were not a sensibility appropriate to the action, and an influence quicker than thought. It is not by feeling the pain of the offensive body, or by estimating its dangers and acting on the conviction, that we close the eye to avoid injuries. This would be an operation all too slow for the intended purpose; and therefore the muscles, possessing these extraordinary provisions, are put in relation with a sensibility more admirable still. So when a light foreign body touches the eyelashes, they give alarm, and cause a motion both of the eyelids and eyeball quicker than thought. The eyelashes, seated on the tender extremities of sensitive nerves, preserve the eye in two ways—by guarding its interior from the lateral light, and by exciting the motion of the eyelids, even before the offensive body can touch the eye's surface.

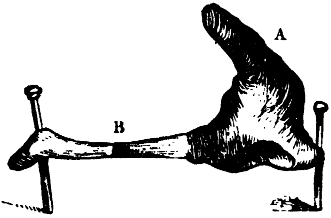
We may take another illustration to show how sensibility, one of the endowments of the living part, is adapted to the mechanical organization, and with an appropriation more admirable than the mechanism. When we speak of the sensibility of the skin, it is still possible to misconceive its nature, and to suppose it accident merely; but in the instance to be adduced, the sensibility is different, and it is put in connection with a hundred muscles; without this high and peculiar sensibility, and its multiplied relations to muscles, independent of volition, the mechanism we are about to describe would be quite useless.

The top of the windpipe is called the *larynx*, and consists of five elastic cartilages. These do not merely keep the sides of the windpipe apart, and the passage for the breath free, but they perform offices important to the economy both of body and mind; they are an essential part of the instrument of voice; they, at the same time, guard the lungs from injury.

The *thyroid* cartilage is the largest of the cartilages of the larynx; it is that we feel projecting on the fore part of the throat called the *pomum adami*, (A.) It is a pro-



tection to the fine apparatus behind it, and indeed this is the reason of its name, (*scutiform*, like a shield.) Within the thyroid stand the *arytænoid* cartilages, (B.) This cartilage is of an irregular triangular form. It is socketed or articulated on the cartilage below, and is perfectly movable. To the corner which projects forwards the



ligament (B) is fixed, and to its other sides five little muscles are attached; these muscles, by moving the cartilage, draw and vary the position of the ligament. It is these cartilages and this ligament, which, vibrating in the stream of air, give the tremor, and vocalize the breath; the tones so produced are articulated in speech.

This is a subject far from being exhausted in our philosophical works, and may call for observation after-

wards; but at present we may look on these ligaments, not as the *cordæ vocales*, but in another of their offices—forming the slit which opens and shuts in breathing, for the protection of the lungs. But here it is pertinent to remark, that in the structure of an animal body one organ is made subservient to several functions, without interference in the performance of any of them. This is especially true of the larynx. It is one of those uses only, and the least important, that we have at present to observe.

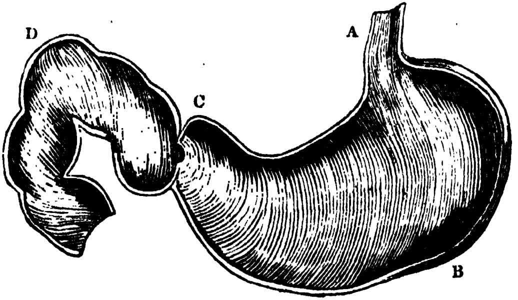
The ligaments being invested with the lining coat, or membrane of the wind-pipe, draw it into the form of a slit like the till of a shop counter, and this is the chink of the glottis, (*rima glottidis.*) This slit opens and closes with every inspiration, moving as we see the nostrils do in breathing. But the most admirable thing of all is the acute sensibility given to this part, and to no other, so that the lightest husk, or seed, or smallest fly, drawn in with the breath, and touching the margin of the chink, is caught there by the rapid action of the muscles and consequent closing of the aperture. Now were the provision for the protection of the lungs to be only thus far perfect, there would be an effectual means of preventing the intrusion of foreign matter into the delicate cells of the lungs, but not for its expulsion from the entrance which it had reached. Accordingly, although the sensibility of the glottis is put in operation with the shutting of the chink, it also animates another class of muscles; viz. all those which, seated on the chest, compress it, and force out the air in coughing; and these combining in one powerful and simultaneous effort, whilst the glottis is closed, overcome that constriction, and propel the breath through the contracted pipe with an explosive force, which brushes off the offending body. There is one thing more, necessary to this most important though familiar action;—the lungs are never empty of air: in breathing we do not fully expel the air; if we did, there would be a period of danger occurring seventeen times in a minute; for in the first part of each inspiration something might be drawn into the wind-pipe which

would suffocate. But by this provision of air retained in the lungs more than necessary to respiration, and which it is possible to expel by a more forcible expiration, there is always a possibility of coughing and expelling the offensive thing at any point of time in the act of inspiration.

The sensibility seated in a spot of the throat so beneficently, does not extend into the wind-pipe; for we cannot more admire the perfect adaptation of this living property, than the circumstance of its never being bestowed in a superfluous degree, nor extended where it is not absolutely required. Just as the sensibility of the skin protects the parts beneath, so in the same manner does the sensibility of the top of the wind-pipe protect all the interior of the tube, and the lungs themselves, without the necessity of this property of irritability extending through the whole continuous surface.

The simple act of sneezing affords a very curious instance of the mutual adaptation of muscular activity and the governing sensibility. The sensation which gives rise to this convulsive act is seated in the membrane of the interior of the nostrils, and we are not surprised with the difference of sensation from that in the throat which excites coughing. But is it not a very curious thing to find some twenty muscles thrown out of the action excited by irritation of the nose; and as many excited which were not in the class of those influenced in coughing; and for the very obvious purpose of shutting the passage by the mouth, or at least forcibly driving the air through the nostrils? No act of the will could so successfully propel the air through the nose in such a way as to remove the offensive and irritating particles from the membrane of the nose, and clear those passages.

These last examples of an appropriate sensibility might introduce us to an acquaintance with those internal sensibilities which govern the actions of parts quite removed from the influence of the will; but the description of them may be deemed unnecessary. We shall just hint at the guard which nature has placed on the lower orifice of the stomach, to check the passage which the appetites



of hunger and thirst may have given at the upper orifice (A) to aliments not easy of digestion. This lower orifice (C) is encircled with a muscular ring; the ring is in the keeping of a watchful guard. If we are employing the language of metaphor, it is of ancient use. The Greeks called this orifice *pylorus*, which signifies a porter,* and his office is this.—When the stomach has received the food, it lies towards the left extremity, or is slightly agitated there. When the digestive process is accomplished, the stomach urges the food towards the lower orifice. If the matter be bland and natural it passes, and no sensation is experienced. But if crude and undigested matter be presented, opposition is offered to its passage, and a contention is begun which happily terminates in the food being thrown again to the left extremity of the stomach, to be submitted to a more perfect operation of the digestive powers seated there. It is during this unnatural retrograde movement of the food, that men are made sensible of having a stomach. Yet the sensations, how unpleasant soever, are not to be regarded as a punishment, but rather as a call on reason to aid the instinctive powers, and to guard against disease, by preventing impure matter from being admitted into the

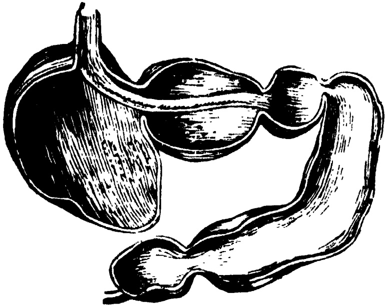
* The upper orifice was called by them *œsophagus*, as it were the *purveyor*, from two words signifying to bring food,

portion of the intestinal canal, which absorbs, and would thus carry those impurities into the blood to engender disease.

Such are a few examples of the variety in the sensibilities of the animal frame; guarding us against external influences when they would threaten destruction to the framework, and adjusting the operations of internal parts too complicated and too remotely situated for the superintendence of reason.

Medical authors, without being empirics, do, notwithstanding, take great advantage of our ignorance. We can all of us take warning from the sensations experienced in the process of digestion, and there can be no harm in giving every man a confidence in the sensibility of his stomach, and in its indications of healthy or disturbed functions. We have the best proof of what we wish to inculcate in the action of the ruminating stomach. A cow swallows the gross herbage, and fills its large first stomach. When it chews the cud, the stomach, by its action, rolls up the grass into distinct pellets, or balls, with as much regard to the office of its being rejected into the mouth as we do in masticating for swallowing. When the ball is brought into the mouth and chewed, it is again swallowed; but in descending into the lower part of the gullet a muscle draws close the aperture by which it passed into the large stomach in the first instance, and it is now ushered into a second stomach, and so successively onwards to that stomach in which the digestion is performed. The curious muscular apparatus by which this is accomplished needs not be described; but surely the sensibility which directs it, which, kept apart altogether from the will, is yet, in its results, so like the operations of reason, presents a subject of just admiration.

The elastic structure of the camel's foot; the provision around its eyes for ridding them of offensive particles; the power of closing its nostrils against the clouds of sand; and its endurance of fatigue—would not enable it to pass the desert, unless there were provisions for the lodgment of water in its stomach, and unless this apparatus were animated by peculiar sensibilities; for there



are muscles to retain the fluid in the cells of its stomach, only permitting it to ooze out according to the necessities of the animal; and there is a muscle, represented in the figure above, which pulls up the one or the other of the orifices of the different stomachs to receive the food from the lower end of the gullet, according to its condition, whether to be deposited merely as in a store, or to be submitted to the operation of digestion.

The surprising thing in all this, is not so much the mechanical provision as the governing sensibility. What, for example, should in the first place impel the grosser food, when collected, into the first stomach? What should, in the next place, and after rumination and mastication in the mouth, carry it into the third stomach; since water is carried into neither of these, but into the cells of the second stomach?

Yet, after all, this only brings us back to a sense of the operations of our own bodies. The act of swallowing, the propulsion of the food into the gullet, and the temporary closing of the windpipe at such a time, is just as surprising. This latter operation is never deranged but by the interference of the will. If the individual attempts to speak, that is, to govern these parts by the will, when they should be left to these instinctive operations; or if terror, or some such mental excitement,

prevail at the moment of swallowing, then the morsel may stick in the throat.

All this shows how perfect the operations of nature are, and how well it is provided that the vital motions should be withdrawn from the control of reason, and even of volition, and subjected to a more uniform and certain law.

But the point to which we would carry the reader is this, that though there are the proper sensibilities of the body, with reference to perception or consciousness, yet there are others no less curious, which control the internal operations of the economy; and that the mechanical provisions are but a type of what is promised to him who will look into the sensibilities of the body for the proof of power and contrivance.

Now the human stomach, though not so complicated in its apparatus of macerating and digesting vats, is possessed of a no less wonderful degree of governing sensibility, which may be trusted as surely as the most skilful physiologist.

We are told that we must not drink at meals, lest the fluid interfere with the operation of digestion; of this there need be no apprehension. The stomach separates, and lets off with the most curious skill, all superfluous fluid through its orifice, while it retains the matter fit for digestion. It retains it in its left extremity, permitting the fluid to pass into the intestines, there to supply the other wants of the system no less important than the digestion. The veterinary professor Coleman ascertained that a pail of water passed through the stomach and intestines of a horse, at the rate of ten feet in the minute, until it reached the cæcum. Drinking at a stated period after meals, say an hour, is at variance with both appetite and reason. The digestion is then effectually interfered with; for what was solid has become a fluid, (the *chyme.*) This fluid is already in part assimilated; it has undergone the first of those changes which fit it ultimately to be the living blood; and the drink mixing with this chyme in the inferior extremity

of the stomach, or first intestine, must produce disturbance, and interrupt the work of assimilation.

Looking in this manner upon the very extraordinary properties of the stomach, we perceive how natural it was for physicians to give a name to the sensibility of which we have been speaking. The *Archeus* of Van Helmont, the *Anima* of Stahl, were the terms used to designate this nature, principle, or faculty, subordinate to, and distinct from perception;—a notion entertained, and more or less distinctly hinted at, by philosophers from Pythagoras to John Hunter.

A modern philosopher,* of whom, in this instance, it would be difficult to say whether he be serious or playful, with some plausibility, however, asserts that it might be possible to carry on the business of life without pain. If animals can be free from it an hour, they might enjoy a perpetual exemption from it. Animals might be constantly in a state of enjoyment; instead of pain, they might feel a diminution of pleasure, and might thus be prompted to seek that which is necessary to their existence.

In the lower creatures, governed by instinct, there may be, for aught we know, some such condition of existence. But the complexity and delicacy of the human frame is necessary for sustaining those powers or attributes which are in correspondence with superior intelligence; since they are not in relation to the mind alone, but intermediate between it and the external material world. Grant that vision is necessary to the developement of thought, the organ of it must be formed with relation to light. Speech, so necessary to the development of the reasoning faculties, implies a complex and exceedingly delicate organ, to play on the atmosphere around us. It is not to the mind that the various organizations are wanted, but to its condition in relation to a material world.

The necessity of this delicate structure being admitted,

* Hume.

it must be preserved by the modifications of sensibility, which shall either instinctively protect the parts, or rouse us into powerful and instantaneous activity. Could the eye guard itself, unless it possessed sensibility greater than the skin? Could it guard itself, unless this sensibility were in consent with an apparatus which acted as quick as thought? Could we, by the mere influence of pleasure, or by any cessation or variation of pleasurable feelings, be made alive to those injuries which might reach the lungs by substances being carried in with the air we breathe? Is there anything but the sense which gives rise to the apprehension of suffocation, that would produce the instant and sudden effort which could guard the throat from the intrusion of what was offensive or injurious? Pleasure is at the best a poor motive to exertion, and rather induces to languor and indulgence, and at length indifference. To say that animals might be continually in a state of enjoyment, and that when urged by the necessities of nature, such as thirst, hunger, and weariness, they might only feel a diminution of pleasure, is not only to alter man's nature, but external nature also; for, whilst there are earth, rocks, woods, and water for our theatre of existence, the textures of our bodies must be exposed to injuries, from which they can only be protected by a sensibility adapted to each part, and capable of rousing us to the most animated exertions. Take away pain, and take also away the material world, by which we are continually threatened with injury; and what, after all, is this, but imagining a future state of existence, instead of that in which mind and matter are combined? If all were smooth in our path, if there were neither rugged places nor accidental opposition, whence should we derive those affections of our minds which we call enterprise, fortitude, and patience?

Independent of pain, which protects us more powerfully than a shield, there is inherent in us, and for a similar purpose, an innate horror of death. "And what thinkest thou (said Socrates to Aristodemus) of this continual love of life, this dread of dissolution, which takes

possession of us from the moment that we are conscious of existence?" "I think of it, (answered he,) as the means employed by the same great and wise artist, deliberately determined to preserve what he has made."

The reader will no doubt here observe the distinction. We have experience of pain from injuries, and learn to avoid them; but we can have no experience of death, and therefore the Author of our being has implanted in us an innate horror at dissolution; and we may see this principle extended through the whole of animated nature. Where it is possible to be taught by experience, we are left to profit by it; but where we can have none, feelings are engendered without it. And this is all that was necessary to show how the life is guarded; sometimes by mechanical strength, as in the skull; sometimes by acute sensation, as in the skin and in the eye; sometimes by innate affections of the mind, as in the horror of death, which will prevail as the voice of nature, when we can no longer profit by experience.

But the highest proof of benevolence is this, that we have the chiefest source of happiness in ourselves. Every creature has pleasure in the mere exercise of his body, as well as in the languor and repose that follow exertion; but these conditions are so balanced that we are impelled to change, and every change is an additional source of enjoyment. What is apparent in the body, is true of the mind also. The great source of happiness is to be found in the exercise of talents, and perhaps the greatest of all is when the ingenuity of the mind is exercised in the dexterous employment of the hands. Idle men do not know what is meant here; but Nature has implanted in us this stimulus to exertion, that she has given to the ingenious artist—the man who invents, and with his hands creates, a source of delight, perhaps greater, certainly more uninterrupted, than belongs to the possession of higher intellectual powers, and far beyond any that falls to the lot of the minion of fortune.

We believe that every thinking person may have wherewithal in his own sphere to tutor him, and bring him to the temper of mind and belief which we would

inculcate. Yet there is something peculiarly appropriate in the study of our own bodies. In chemistry we are so much the agents as to forget the law, and the law itself seems at least to intermit. But in the changes wrought in the animal frame, the directing power is uniform in its influence, and holds all in harmony of action.

We now learn without difficulty and without mystery, what is meant by organic and animal sensibility. The first is that condition of the living organ which makes it sensible of an impression, on which it reacts and performs its functions. It appears from what has preceded, that this sensibility may cause the blowing of a flower, or the motion of a heart. The animal sensibility is indeed an improper term, because it would seem to imply that its opposite, organic sensibility, was not also animal; but it means that impression which is referred to the sensorium; where (when action is excited) perception and the effort of the will are intermediate agents between the sensation and the action or motion.

We may sum up the inquiry into sensibility and motion thus:—

1. The peculiar distinction of a living animal is, that its minute particles are undergoing a continual change or revolution under the influence of life. Philosophers have applied no term to these motions.

2. An organ possessed of an appropriate muscular texture, and of sensibility in accordance with the moving instrument, as the heart, or the stomach, has the power of action without reference to the mind. The term *automatic*, sometimes given to those motions, conveys a wrong idea of the source of motion, as if, instead of being a living power, it were consequent upon some elastic or mechanical property.

3. There are sensibilities bestowed on certain organs, and holding a control over a number of muscles, which combine them in action in a manner greatly resembling the influence of the mind upon the body, yet independent of the mind; as the sensibility which combines the muscles in breathing.

4. In the last instance a large class of muscles were

combined without volition. But the whole animal fabric may be so employed; as in the instinctive operations of animals, where there is an impulse to certain actions not accompanied by intelligence.

5. A motive must exist before there are voluntary actions, and hence philosophers have supposed that there can be nothing but instinctive actions in a new-born child. But we must distinguish here what are perfect at first, and what are imperfect and irregular, and become perfect by use and the direction of the will. The act of swallowing is perfect from the beginning. The motions of the legs and arms, and the sounds of the voice, are irregular and weak, and imperfectly directed. It is the latter which improve with the mind. From not knowing the internal structure, and the arrangement of the nerves, philosophers, as Hartley, supposed that an instinctive motion, such as swallowing, may become a voluntary act. Volition in the act of swallowing consists merely in putting the morsel within the instinctive grasp of the fauces, when a series of involuntary actions commence, over which we have no more control in mature age than in the earliest infancy. Swallowing is not a voluntary action, and the thrusting the morsel back with the tongue is like putting the cup to the lip. It is the preparation for the act of swallowing that is voluntary, but over the act itself we have no control.

It is an error to suppose that all muscular actions are, in the first instance, involuntary, and that over some of them we acquire a voluntary power. The power of volition over the muscles of the body is provided for by appropriate nerves, and no apparatus which is not supplied with that particular class of nerves can ever, by any exercise or study, become subject to volition. A child's face has a great deal of motion in it, very diverting from its resemblance to expression, before there can be any real motive to the action. It will crow, and make strange sounds, before there is an attempt at speech. But this gradual development of intelligence and acquisition of power ought not to be called the will attaining influence over involuntary muscles; since, in fact, the

apparatus of nerves and muscles is prepared and waits for the direction of the mind with so perfect a readiness, as to fall into action and just combination before that condition or affection of the mind which should precede the action takes place. A child smiles before anything incongruous can enter the mind, before even pleasure can be supposed a condition of the mind. Indeed, the smile on an infant's face is first perceived in sleep.

6. All the motions enumerated above are spontaneous motions belonging to the internal economy; but the external relations of the animal, the necessity of escaping from injury, or warding off violence, require a sensibility suited to those outward impressions, and an activity consequent on volition. Nothing less than perceptions of the mind, and voluntary acts, suited to a thousand circumstances of relation, could preserve the higher classes of animals, and man above all others, from destruction.

All these provisions proceed from an arrangement of nerves and muscles. The mechanical adjustment of the muscles and tendons is perfect according to the principles of mechanics. The muscles themselves possess a different property; they are irritable parts; motion originates in them. This living property of contraction is admirably suited, in each particular muscle, to the office it has to perform. In some it is suitable that the muscles should act as rapidly as the bowstring on the arrow; in others the action is slow and regular; in others it is irregular, and after long intervals, according as the functions to which they are subservient require. The motions of the limbs, the motions of the eye, those of the heart and arteries, stomach and bowels, are all different. This appropriation of action is not in the muscles themselves, but as they stand in relation to the nervous system, and the sensibilities which impel them.

We hope, then, by the course we have taken, that we have carried the reader to a higher sense of the perfection of the animal structure. We first drew him to observe provisions in the strengthening of the bones, the adjustment of their extremities to the joints, the course of the tendons, and other such mechanical appliances,

proving to him the existence of intention in the formation of the solid fabric of the body. We have then explained how that motion is produced which was at all times familiar to him, but even the immediate causes of which he did not comprehend. We have, in the last place, shown him that under the term life he has a still more admirable subject of contemplation in the adjustment of those living properties; in the sensibilities differing not so much in degree as in kind; and in their appropriation, both to the operations of the internal economy, and to the relations external, and necessary to safety.

It is not possible to contemplate these things without having the full proof before us of the power of the Creator in forming and sustaining the animal body. As a man with *gutta serena* may turn his eyes to the sun, and feel no influence of light; so may the understanding be blind to these proofs; and we may say, with the celebrated Dr. Hunter, that he who can contemplate them without enthusiasm, must labour under a dead palsy in some part of his mind, and we must pity him as unfortunate.

CHAPTER IV.

OF THE CHANGES IN THE MATERIAL OF THE ANIMAL BODY DURING LIFE.

WE have seen the motions performed in the animal body through the actions of the muscles and the play of the mechanical parts, and we have had occasion to reflect on the action of the heart and the motion of the blood in the circulation; but these are as nothing compared with the interest of our present subject—the changes going forward in the solid material of the frame. Is it not surprising that the individual who retains every peculiarity of body and of mind, whose features, whose gait and mode of action, whose voice, gestures, and complexion we are ready to attest as the very proof of personality, should in the course of a few days change every particle of his solid fabric?—that he whom we suppose we saw, is, as far as his body is concerned, a perfectly different person from him we now see? That the fluids may change we are ready to allow, but that the solids are thus ever shifting seems at first improbable. And yet, if there be any thing firmly established in physiology, if there be truth in the science at all, this fact is incontrovertible.

There is nothing like this in inanimate nature. It is beautiful to see the shooting of a crystal;—to note, first, the formation of integrant particles from their elements in solution, and these, assuming a regular form under the influence of attraction or crystalline polarity, producing a determinate shape; but the form is permanent. In the different processes of elective attraction, and in fermentation, we perceive a commotion, but in a little time the products are formed, and the particles are at rest. There is in these instances nothing like the revolutions

of the living animal substance, where the material is alternately arranged and decomposed. The end of this is, that the machinery of the body is ever new, and possesses a property within itself of mending that which was broken, of throwing off that which was useless, and of building up that which was insecure and weak; of repelling disease, or of controlling it, and substituting what is healthful for that which is morbid. The whole animal machinery we have seen to be a thing fragile and exposed to injury; without this continual change of material, and this new modelling of that material, our lives would be more precarious; the texture of our bodies would be spoiled like some fine piece of mechanism which had stopped, and no workman would have science sufficient to reconstruct it. But by this process, the minute particles of the body die successively; not as in the final death of the whole body, but part by part is deprived of its vitality and taken away into the general circulation, whilst new parts are endowed with the property of life, and are built up in their place. By this revolution, we see nature, instead of having to establish a new mode of action for every casualty, heals all wounds, unites all broken bones, throws off all morbid parts by the continuance of its usual operations; and the surgeon who is modest in his calling, has nothing to do but to watch, lest ignorance or prejudice interfere with the process of nature. This property of the living body to restore itself when deranged, or to heal itself when broken or torn, is an action which so frequently assumes the appearance of reason, as if it were adapting itself to the particular occasion, that even the last great luminary in this science, Mr. John Hunter, speaks of parts of the body, as "conscious of their imperfection," and "acting from the stimulus of necessity," thus giving the properties of mind to the body, as the only explanation of phenomena so wonderful.

We make a moderate assumption, when we declare these changes to be under the guidance of the living principle. In a seed, or a nut, or an egg, we know that there is life, and from the length of time that these bodies

will remain without change, we are forced to acknowledge that this life is stationary or dormant, and limited to the counteraction of putrefaction or chemical decomposition; but no sooner does this principle become active, than a series of intestinal or internal changes are commenced, which are regularly progressive, without a moment's interruption, while life continues.

That principle which may continue an indefinite number of days, months, or years, producing no change in all this time, begins at once to exhibit its influence, builds up the individual body, regulates the actions of secretion and absorption; and, by its operation upon the material of the frame, stamps it with external marks of infancy, maturity, and age.

But let us examine the proofs of this universal change in the material of the body. It is not very long since a bone was supposed to be a concrete juice, and that the liquid parts were converted into solids, as we see mortar or Paris plaster from fluid assuming a solid form. But the anatomist began to observe, that the bones were porous; that these pores admitted membranes and vessels; and some went so far before their brethren, as to assert that they saw arteries, veins, lymphatics, and nerves going into the bone; in short, the opinion gradually grew stronger, that they were living parts, and subject to all the changes to which the softer parts of the living body were liable. An accident gave admirable proof of this. It was found that the bones of pigs, fed with the refuse of the dyer's vats, in which madder was contained, became tinged of a beautiful red colour. It was this fact which ingenious physiologists made use of, and which enabled them to demonstrate the rapidity with which the old bone was carried away, and new bone substituted. The physiologist observed, that if he threw a bone into the fire, what is called the animal part was burned and dissipated, but there remained, imperishable by this process, a mass of earth, which proved to be the phosphate of lime. He thought of varying his experiment, and put the bone into acid, which dissolved that phosphate of lime, and left the bone to all outward appearance as

before. It had its form, its membranes, its vessels, but when pressed it proved to be soft and pliant; the phosphate of lime having been dissolved and extracted, it was no longer capable of the office of a bone, to bear the weight and motions of the body. When the experiments with madder were resumed, it appeared that when this earth of bone was about to be secreted from the circulating vessels, and deposited in the membranes of the bone, it met with the colouring particles of the madder in the blood; and, as the chemist would explain, the madder and the phosphate of lime were precipitated, and filled all the interstices of the membranes and vessels. We shall not stop here to inquire into the admirable manner in which this hardening material of bone is deposited for the purposes of strength—it is only the change upon the material which we have now to contemplate.

If this earth of bone, so coloured, had beeen deposited for a permanency, and built into these cells and crevices, like brick and mortar, the colour would remain; but, however deeply the bones of an animal may be tinged in this manner, the colour is not permanent, unless the animal continue to be fed with the madder. If its food be pure of the madder, even for a few weeks, and if after this the animal be killed, its bones are white, that is to say, the old particles of phosphate of lime are carried away by absorption, and with them the colouring material; and that newer bone which is deposited by the arteries is untinged and pure, having no colouring material to attract.

It is unnecessary to follow out those curious experiments by which the physiologist has shown the rapidity of the formation of a new bone around the broken end of an old one, and the deep tinge such new bone takes, compared with the fainter colour of that which had been perfect, previous to the feeding with madder; the manner in which, by feeding the animal alternately with madder and without it, he contrives to exhibit different coloured layers in the growing bone. It is sufficient for our purpose, to know that the densest part of the animal frame is subject to change, like the most delicate texture of the

body, and that the only means of arresting the motion is to deprive it of life; if a part of a bone be killed by the application of a cautery, that moment it becomes permanent, and is subject to no change, whilst all the parts around it are undergoing their revolutions.

The bones of the legs and thighs, which suffer the fatigue of motion, and which support the weight of the body, without diminishing in their length, or altering in the slightest measureable degree their proper form, are nevertheless undergoing an operation of repair, in which the old particles are withdrawn, whilst new ones replace them. We see with what care the walls of a house are shored up to admit of repair—how carefully the workman must estimate the strength of his pillars and beams—how nicely he must hammer in his wedges, that every interstice may be filled, and no strain permitted; and if this operation fail in the slightest degree, it is attended with a rent of the wall from top to bottom. We say, then, that by the very awkwardness of this process, in which, after all, there is danger of the whole fabric tumbling about the workmen, we are called upon to admire how the solid pillars in our own frame are a thousand times renewed, whilst the plan of the original fabric is followed to the utmost nicety in their restoration. And if it deviate at all, it is only in a manner the more to surprise us, since, on examination, it will be discovered to result from an adaptation of the strength of material to some new circumstance, the increasing weight it has to support, or the jar that it is subject to, from the change in the activity or exercise of the body.

There is a disease of the bone which illustrates this in a surprising manner, and proves to us, that however diseased and monstrous in its shape the bone may be, yet there is a natural law operating, which by its prevalence will overcome the morbid action, and from a shapeless mass restore the bone to its natural condition.

This disease is called *necrosis*, which word signifies the *death* of the bone merely; but it is death in very peculiar circumstances; a new bone is formed around the old one; a large and clumsy cylinder is fashioned of

the earth of bone, in the hollow of which the shaft of the old bone is contained. After a long time the old bone comes out through this new case, and with the aid of the surgeon it is altogether withdrawn from the limb. During all this process the patient is capable of supporting his weight upon that limb, so that it resembles on a large scale that change which we have described as going continually on in the molecules of the bone; a new part is substituted, and the old taken away.

If workmen were to take away a pillar in the following manner, their work would resemble the process of necrosis: first, they must rear a hollow cylinder around the old pillar, resting on the plinth and base, and extending to the capital, and having secured the union of the cylinder at top and bottom to the extremities of the pillar, they must take away the shaft, or middle piece, of the old pillar by perforating the new cylinder.

The reader may easily imagine that when this process is completed in a man's limb, it will be as clumsy as the leg of an elephant, large, firm, and shapeless; but the extraordinary circumstance is still to be described.—This new bone is gradually diminished in its exterior surface, and its hollow filled up, and thus, by a change scarcely perceptible, it resumes the form and dimensions of the original bone; and, after a time, the anatomist might examine this limb and find neither in the articulating surfaces, nor in the spines and ridges, nor in the points of attachment for ligaments and muscles, any thing to indicate the extraordinary revolution that had taken place.

What explanation have we to give of this change? There can be no doubt that the material is not the same; for we have the old bone in our hand, and the man is walking upon a new bone. Yet extraordinary, then, as this appears, it is not more inexplicable than the common phenomenon of the growth of an infant to maturity. There is a living principle which is permanent while the material changes; and this principle attracts and arranges, dissolves and throws off successive portions of the solids. There is a law influencing this living prin-

ciple, which, in its operation on the material, shapes and limits the growth of every part, and carries it through a regular series of changes, in which its form and aptness for its office are preserved, whilst the material alone is altered.

The influence of disease will for a time disorder this modelling process and produce tumours and distortions; but when at length the healthy action, that is, the natural action, prevails, these incumbrances are carried away, and the fair proportions of the fabric are restored.

It is very pleasing to observe the different means employed where a slight change of circumstances demands it. This earth of bone—the phosphate of lime—is changing continually; but the teeth admit of no change; they consist of earth too—the phosphate, carbonate, and fluate of lime. Bodies calculated for such violent attrition, and with a surface so hard as to strike fire with steel, would be ill accommodated with such a property of changing as we have seen in the bones. They must therefore fall out and be succeeded by new ones; and this process, familiar as it may be, is very curious when philosophically considered.

There are no teeth whilst yet the infant is at the breast; and when they rise they are attended with new appetites, and a necessity for change of food. When perfected they form a range of teeth, neat and small, adapted to the child's jaws and the size of its bones. Were they to grow at once, or to fall out at once, it would prove a disturbance to the act of eating. They fall in succession; their fangs are absorbed, they are loose and jangling, and are easily extracted. But now comes the question, why are these teeth of the infant old at six years? Why are those that are to succeed and be stationary for a series of years, to germinate and grow at the appointed time like the buds in the axilla of a leaf? And when fully formed, why do they remain perfect for sixty years instead of six; at the end of which term the first set were old and decayed? No difference can be observed in the material of the teeth of the first or second set. The one will be as perfect as

the other after remaining a hundred years in a charnel house. Can any one refuse his belief, then, when he sees so accurate a mechanical adaptation of the teeth to their places and their offices; can he, we say, refuse assent to this also, that there is a law impressed—a property by which the milk teeth shall fail and be discharged from the jaw in six years, whilst the others will last the natural life of the adult, if not injured by accidents to which all parts are subject? This is not the only instance in which parts of the body lie dormant for a term of years, and are at a particular period of life developed and perfected—and which have, we may say, their time of infancy, perfection, and decay, whilst yet there is no material deterioration observable in the general frame.

We are thus brought to the consideration of a question which has not yet been fairly stated.

Those who say that life results from structure, and that the material is the ruling part, bid us look to the contrast of youth and age. The activity of limb and buoyancy of spirit they consider as a necessary consequence of the newness and perfection of organization in youth. On the other hand, a ruined tower, unroofed, and exposed to be broken up by alternation of frost and heat, dryness and moisture, wedged by the roots of ivy, and tottering to its fall, they compare with old age—with the shrunk limbs, tottering gait, shrivelled face, and scattered grey hair of the old.

But in all this there is not a word of truth. Whilst there is life and circulation there is change of the material of the frame (and there is a sign of this if a broken bone unites or a wound heals). Ascribe the distinction to the rapidity of change, to the velocity of circulation, or to the more or less energy of action; but with the antiquity of the material it can have nothing to do. The roundness and fulness of flesh, the smoothness, transparency, and colour of the cheek, belong to youth, as characteristic of the time of life, not as a necessary quality of the material! Is there a physiognomy in all nature—among birds and beasts, and insects and flowers—and

shall man alone have no indication of his condition in the outward form and character?

The distinctions in the body, apparent in the stages of life, have a deeper source than the accidental effects of the deterioration of the material of the frame. The same changes which are wrought on the structure of the body in youth and in the spring of life are going on in the last term of life; but the fabric is rebuilt on a different plan. The law of the formation is still inherent in the life which has hurried the material of the body through a succession of changes; and each stage, from the embryo to the fœtus, the fœtus to the child, from that to adolescence, to maturity, and to the condition of old age, has its outward form, as indicative of internal qualities, but not of the perfection or imperfection of the gross material. We might as well consider the difference in the term of life of the annual or biennial plant as compared with the oak, or the ephemeris fly as compared with the bird that hawks at it, to be in the qualities of the matter which forms them, as that the outward characters of the different stages of human life arose from the perfection or imperfection of the material of the body. Not only has every creature its appointed term of life, but we have shown that parts of the human body do not, in this respect, bear a relation to the whole; organs are changed and disappear; others, in the mean time, at their regulated period, shoot to perfection, and again decay before the failure of the body. What can more distinctly show that it is the principle of life that directs all; and that on it the law is imprinted which orders our formation, and all the revolutions we undergo? The material of the body, solid and fluid, is moved by this influence, and varies every day, part by part dying every hour, and renewed, until the series of its changes on the gross material of the body is accomplished in an entire and final separation.

The grand phenomena of nature make powerful impression on our imagination, and we acknowledge them to be under the guidance of Providence; but it is more pleasing, more agreeable to our self-importance, it gives

us more confidence in that Providence, to discover that the minutest changes in nature are equally His care, and that "all things do homage."

Although it be true that every thing in nature, being philosophically contemplated, will lead to the same conclusions, yet the occurrences around us steal so imperceptibly on our observation, all the objects of nature, or at least vegetable and animal productions, grow up by so slow a process by our side, that we do not consider them at all in the same way as we should do if they started suddenly upon our vision.

It is this familiarity with the qualities of a living body, and a habit of seeing without reflection, which has made it necessary to carry the reader through so long a course of observation and reasoning to excite attention to the admirable structure of his own frame, and its adaptation to the earth we inhabit—to perceive that every thing is formed with a strict relation to the human faculties and organs, to extend our dominion and to multiply our sources of enjoyment. It is by seeing the plan of Providence in the establishment of relations between the condition of our being and the material world, that we learn to comprehend that unity of design in the creation in which we form so great a part.

This exaltation of our nature is not like the influence of pride or common ambition. We may use the words of Socrates to his scholar, who saw in the contemplation of nature only a proof of his own insignificance, and concluded "that the gods had no need of him," which drew this answer from the sage: "The greater the munificence they have shown in the care of thee, so much the more honour and service thou owest them!"

LONDON WILLIAM CLOWES AND SONS, STAMFORD STREET

NEW WORKS

PUBLISHED BY

RICHARD GRIFFIN AND COMPANY.

LORD BROUGHAM'S

CRITICAL, HISTORICAL, & MISCELLANEOUS WORKS,

In a series of Post 8vo. Volumes, Price 5s. each,

TO BE PUBLISHED QUARTERLY.

Vol. 1.—Lives of Philosophers of the Time of George III., comprising BLACK, WATT, PRIESTLEY, CAVENDISH, DAVY, SIMSON, ADAM SMITH, LAVOISIER, BANKS, and D'ALEMBERT.

Vol. 2.—Lives of Men of Letters of the Time of George III., comprising VOLTAIRE, ROUSSEAU, HUME, ROBERTSON, JOHNSON, and GIBBON.

Vols. 3, 4, 5.—Sketches of Eminent Statesmen of the Reign of George III., new edition, enlarged and corrected, 3 vols.

TO BE FOLLOWED BY

Dissertations and Addresses on Literature, Philosophy, and Natural Theology.

Speeches on Social and Political Subjects, with Historical Introductions.

Critical and Historical Dissertations from the Edinburgh Review, &c.

"What a marvellous variety of study and argument; what a faculty must there be for readily abstracting the mind from one subject and concentrating it upon another! And yet, contrary to the vulgar opinion, that one man can only excel in one thing, how well is all here done. Whether it be biography, history, oratory, or science, it is the best of its kind; every page sparkles with profound thought and original conception. Lord Brougham is never dull or prosy, whether discoursing of philosophy or politics. In his hands science is amusing, because he treats it familiarly, and is content to discourse in plain English when he addresses himself to an English audience. His biographies have a peculiar interest; for he was personally acquainted with many of the distinguished men whose lives he narrates, and he introduces characteristic anecdotes that give a better knowledge of the person than the most elaborate description."—*Critic.*

Cabinet Edition of the Encyclopædia Metropolitana—*continued.*

Vol. XI., price 5s., cloth lettered,

Introduction to Universal History—On the Uses of History as a Study, and On the Separation of the Early Facts of History from Fable. By Sir JOHN STODDART, LL.D. Re-written.

Vol. XII., price 8s. 6d., cloth lettered,

Roman Antiquities. By WILLIAM RAMSAY, M.A., Professor of Humanity in the University of Glasgow. With Map, and One Hundred and Thirty Illustrations. Third Edition.

Vol. XIII., price 10s. 6d., cloth lettered,

Botany. By JOHN HUTTON BALFOUR, M.D., F.L.S., F.R.S.E., Professor of Botany in the University of Edinburgh. Third Edition, revised by JOSEPH WILLIAMS, M.D. Numerous Engravings.

Vol. XIV., price 3s. 6d., cloth lettered,

Electro-Metallurgy: Containing an Account of the most Improved Methods of Depositing Copper, Silver, Gold, and other Metals. By JAMES NAPIER, F.C.S. Second Edition.

Vol. XV., price 9s., cloth lettered,

History of Greece from the Earliest Times to the Close of the Peloponnesian War. By E. POCOCKE, Esq.; Sir T. N. TALFOURD, D.C.L., and others. One Hundred Engravings.

Vol. XVI., price 6s., cloth lettered,

Photography. By ROBERT HUNT, F.R.S., Museum of Economic Geology, London. Fourth Edition, Numerous Engravings.

Vol. XVII., price 3s., cloth lettered,

Veterinary Art: A Practical Treatise on the Diseases of the Horse. By W. C. SPOONER, Esq., with 50 Engravings.

Vol. XVIII., price 8s., cloth lettered,

Early Oriental History, comprising the History of the Egyptians, Assyrians, Phœnicians, Persians, &c. By the Rev. Professor EADIE, D.D., LL.D. With Numerous Illustrations.

Vol. XIX., price 8s. 6d., cloth lettered,

History of the Roman Republic. By the Rev. THOS. ARNOLD, D.D.; Sir THOMAS N. TALFOURD, D.C.L.; the Rev. Professor JEREMIE, and others. With Numerous Illustrations.

Vol. XX., price 7s. 6d., cloth lettered,

Biblical Antiquities and Geography, including the Language, Geography, and Early History of Palestine. Edited by the Rev. F. A. COX, D.D., LL.D. With Maps and Numerous Illustrations.

Vol. XXI., price 12s. 6d., cloth lettered,

Metallurgy. A Practical Treatise on the Chemistry of the Metals. By JOHN ARTHUR PHILLIPS, Esq., F.C.S. Second Edition, revised. Illustrated by nearly 200 Engravings.

Cabinet Edition of the Encyclopædia Metropolitana—*continued.*

Vol. XXII., price 4*s.*, cloth lettered,

History of the Christian Church in the Second and Third Centuries. By James Amiraux Jeremie, D.D., Regius Professor of Divinity, Cambridge.

Vol. XXIII., price 8*s.*, cloth lettered,

History of Greece and Macedonia; from the Age of Xenophon to the absorption of Greece in the Roman Empire. By Dr. Lyall, Dean of Canterbury, Rev. G. C. Renouard, B.D., &c.

Vol. XXIV., price 10*s.* 6*d.*, cloth lettered,

History of Roman Literature. By the Rev. Thomas Arnold, D.D.; Rev. Henry Thompson, M.A.; Rev. Dr. Newman; Rev. J. B. Ottley, M.A.; and Rev. J. M. Neale.

Vol. XXV., price 10*s.* 6*d.*, cloth lettered,

History of the Roman Empire. By the Rev. Thomas Arnold, D.D., late Head Master of Rugby School, and others. With Numerous Illustrations.

Vol. XXVI., price 10*s.* 6*d.*, cloth lettered,

History of the Decline and Fall of the Roman Power. By the Right Rev. Bishop Russel, &c. With Numerous Illustrations.

Vol. XXVII., price 6*s.*, cloth lettered,

History of Greek and Roman Philosophy and Science. By the Right Rev. Charles Blomfield, D.D., Bishop of London; Rev. Dr. Whewell, and other Contributors.

Vol. XXVIII., price 3*s.* 6*d.*, cloth lettered,

Moral and Metaphysical Philosophy—The Philosophy of the First Six Centuries. By the Rev. F. D. Maurice, M.A.

Vol. XXIX., price 7*s.* 6*d.*, cloth lettered,

History of the Ottoman Empire; including a Survey of the Greek Empire and the Crusades. By Colonel Procter, Rev. J. E. Riddle, and James M'Conechy, Esq.

Vol. XXX., price 2*s.* 6*d.*, cloth lettered,

Trigonometry. By George B. Airy, F.R.S., Astronomer Royal. Edited by Hugh Blackburn, M.A., Professor of Mathematics in the University of Glasgow.

Vol. XXXI., price 6*s.*, cloth lettered,

Occult Sciences; Containing the Traditions and Superstitions of past times, and the Marvels of the present day. By the Rev. Edward Smedley, M.A., E. Rich, Esq., and others.

Vol. XXXII., price 12*s.* 6*d.*, cloth lettered,

Geology—Practical and Theoretical. By John Phillips, M.A., F.R.S., F.G.S., Deputy Reader in Geology in the University of Oxford. With Numerous Illustrations.